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Overland Flow Treatment of Municipal Sewage at Easley, South Carolina

Clemson Univ., SC

Prepared for

Robert S. Kerr Environmental Research Lab.
Ada, OK

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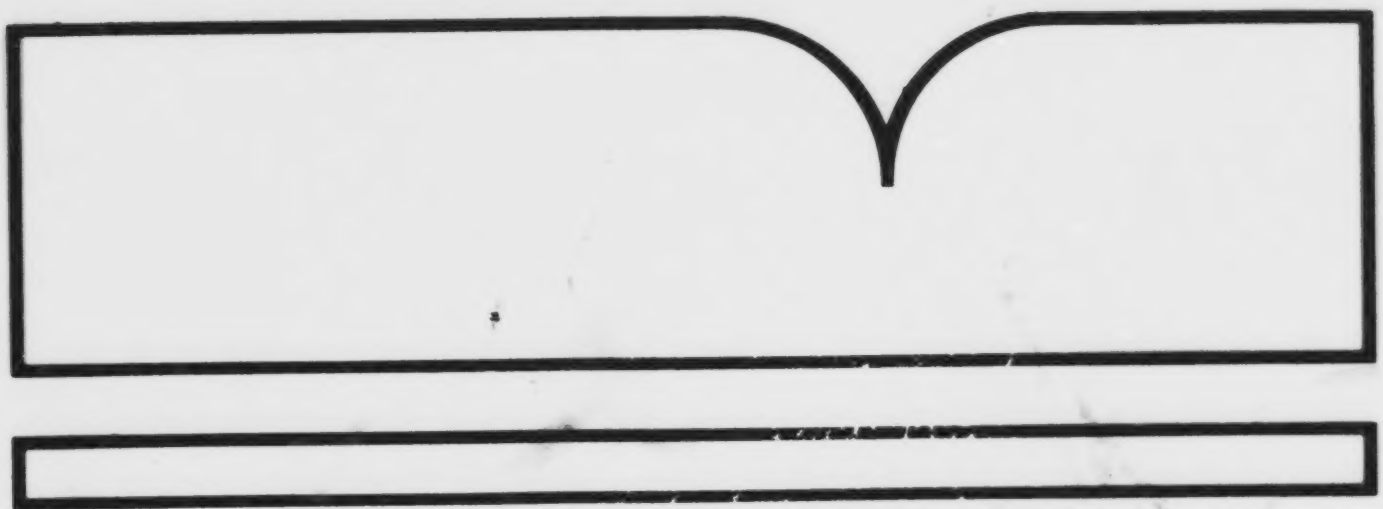

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OVERLAND FLOW TREATMENT OF MUNICIPAL SEWAGE AT EASLEY, SC

by

A. Ray Abernathy
Environmental Systems Engineering Department
Clemson University
Clemson, SC 29631

CR 803929

Project Officer

Bert E. Bledsoe
Wastewater Management Branch
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma 74820

Robert S. Kerr Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

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Overland flow has been demonstrated to be a feasible method for treatment of either comminuted raw sewage or effluent from a facultative lagoon in piedmont South Carolina where mild winters prevail in a region of high rainfall. An overland flow system was operated for three years at Easley, South Carolina, to treat 284 cubic meters per day (75,000 gpd) of facultative lagoon effluent and 95 cubic meters per day (25,000 gpd) of comminuted raw sewage. Multiple plots were constructed to allow estimation of the effects of various combinations of application rate and frequency according to a second order statistical design. Influent and effluent measurements of classical pollution parameters were made to evaluate the system performance. The system was monitored for bacterial aerosols and the influence of the system on the existing groundwater aquifer.

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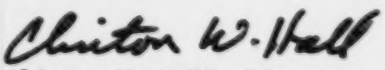
FOREWORD

EPA is charged by Congress to protect the Nation's land, air, and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, is charged with the mission to manage research programs: to investigate the nature, transport, fate, and management of pollutants in ground water; to develop and demonstrate technologies for treating wastewater with soils and other natural systems; to control pollution from irrigated crop and animal production agricultural activities; and to develop and demonstrate cost-effective land treatment systems for the environmentally safe disposal of solid and hazardous wastes.

The purpose of this project was to demonstrate the feasibility of using one of the three major land treatment processes, overland flow, to treat both comminuted raw sewage and effluent from a facultative lagoon in a region of high rainfall and mild climate. The U.S. Environmental Protection Agency had been encouraging the use of natural treatment systems and this project was initiated to use currently available design criteria for this system. The continued monitoring resulted in improved design, along with detailed cost of construction and operation.



Clinton W. Hall, Director
Robert S. Kerr Environmental Research Laboratory

PREFACE

Interest in land treatment of domestic wastewater has greatly increased since Public Law 92-500 gave emphasis to reclamation and recycle. The decision within EPA to accept land treatment and disposal as innovative and alternative technology has also accelerated the trend.

One of the three major land treatment processes is overland flow, in which wastewater is applied to the upper portion of a grass covered slope and allowed to flow over the surface to runoff-collecting ditches at the foot of the slope. This process has been used for food processing wastewater in this country and for domestic sewage at Melbourne, Australia. Lack of operating experience and proven design criteria for overland flow treatment of domestic sewage led to the planning for this project. It was hoped that additional operating experience and demonstrated success of overland flow treatment of domestic sewage would simultaneously result in improved design criteria and increased demand for these criteria by municipalities and design engineers.

The Easley Overland Flow Project has successfully demonstrated that overland flow can treat both comminuted raw sewage and effluent from a facultative oxidation pond or lagoon. Efficient operation has been achieved during all seasons in this high rainfall region. The results of this project indicate that minimal treatment of domestic sewage before application to overland flow plots results in cost effective treatment with good quality effluent. The major problem observed in treating lagoon effluent was the tendency of algal cells to move across the slope with the water and exit with the runoff. This often resulted in suspended solids concentration greater than 30 mg/l, although other parameters more than satisfied secondary treatment criteria.

Overland flow should be given serious consideration for treating domestic sewage from small municipalities where appropriate land is available at reasonable cost. This process can consistently produce a good quality effluent without excessive energy consumption or high operating costs.

ABSTRACT

Overland flow has been demonstrated to be a feasible method for treating either comminuted raw sewage or effluent from a facultative lagoon in piedmont South Carolina where mild winters prevail in a region of high rainfall. An overland flow system has been used for three years at Easley, SC to treat 284 cubic meters per day (75,000 gpd) of facultative lagoon effluent and 95 cubic meters per day (25,000 gpd) of comminuted raw sewage. The system was designed for separate pumping and distribution of each wastewater; multiple plots were constructed to allow estimation of the effects of various combinations of application rate and frequency according to a second order statistical design.

Influent and effluent measurements of BOD_5, organic carbon, suspended solids, and nitrogen and phosphorus species were made to evaluate system performance. Samples were also collected at intervals down the plots to determine profiles of removal of the various parameters.

For the raw sewage application system, total BOD_5 (87% reduction) and suspended solids (85% reduction) were readily removed. Nitrogen (62% reduction as total nitrogen) and phosphorus (50% reduction as total phosphorus) removals were observed to be a function of plot length.

Hydraulic factors influencing the removal of algal solids determined system performance for the lagoon effluent system with respect to suspended solids. The lagoon effluent system usually produced a final effluent higher in suspended solids concentration than the effluent from plots receiving raw sewage. On the other hand, final effluent was lower in BOD_5, total phosphorus, and total nitrogen than the effluent from plots receiving raw sewage. The plots removed (based on concentration) an average of 55% total BOD_5, 45% of suspended solids, 67% of total nitrogen and 34% of the total phosphorus in the lagoon effluent.

Both systems equaled or exceeded typical secondary treatment systems in the consistent quality of their effluent. Operating costs were less than $10,000 per year for the nominal flow of 380 cubic meters per day (100,000 gpd). The nonresearch operating cost would be 64 percent of the yearly cost.

The system was monitored for bacterial aerosols and the influence of the system on the existing groundwater aquifer. Air monitoring stations were located both upwind and downwind of the spray risers. Ten sampling wells were installed to sample the aquifer both above and below the system.

This report was submitted in fulfillment of Cooperative Agreement CR803929 by Clemson University under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period November 1976 to November 1981, and work was completed as of December 31, 1981.

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SECTION I

INTRODUCTION

OBJECTIVES OF THE PROJECT

The major objective of this project was to evaluate the feasibility of the overland flow system for the treatment of domestic wastewater in a region of high rainfall, low soil permeability, and mild climate. It was hoped that by designing, constructing, and operating such a system, improved design and operating criteria could be developed, and that increased interest would be generated among municipal officials and design engineers in using this land treatment process. This project thus combined some aspects of a demonstration project and some aspects of a research project.

In order to achieve the major objective it was necessary to locate a site in western South Carolina where soil conditions, availability of land, and an existing sewerage system made such a project feasible. It was also desirable that a lagoon be present in order to treat both comminuted raw sewage and facultative lagoon effluent by overland flow.

These factors combined with a location within a distance of 48 kilometers (thirty miles) or less from Clemson University was considered important, since samples would be collected by personnel from Clemson and transported to the Environmental Systems Engineering Department laboratories for analyses.

SUMMARY OF PREVIOUS WORK

Since little quantitative design data was available, a survey of existing overland flow systems was made to summarize design criteria utilized and results obtained. These systems can be categorized in two groups: those which treat the entire waste stream and those which divert only a portion of a total waste stream for treatment by overland flow. The latter emphasize research whereas the former are production oriented and must dependably treat the entire wastewater flow. Efforts were made to combine criteria from both types to yield an efficient as well as dependable design.

The largest, oldest, and probably best known overland flow site is the Melbourne, Australia municipal farms system. It was begun in 1893, by a British engineer (49). In 1975 the system treated over 378,500 cubic meters per day (100 MGD) of municipal sewage by irrigation, overland flow and lagoons. The total site, including beef pasture land, is about 10,900 hectares (27,000 acres). Of this total, 1,400 hectares (3,500) are used for overland flow or grass filtration as it is labeled in Australia (65). The soils consist of about 15 cm (six inches) of loam overlying clay subsoils in an arid locality. Virtually all suspended material is removed on or in the soil. Monitoring records since 1891 indicate very little change in water table levels. There is no evidence of a salinity build-up (50).

The Melbourne influent quality is similar to typical domestic sewage with the combined effluent from all treatment trains on the site averaging about 30 mg/l suspended solids and 20 mg/l BOD. Since the discharge from 1,375 hectares (3,400 acres) of lagoons is contained in this final effluent, it is probable that overland flow effluent may well be of a higher quality than the combined effluent. The application rate on the overland flow area is up to 5 cm (two inches) per week and the wastewater is distributed and applied by a network of channels (49).

Campbell Soup's project in Paris, Texas is the largest overland flow site in the United States. It utilizes 200 hectares (500 acres) to treat 13,600 cubic meters per day (3.6 MGD) of cannery wastewaters (78). This type of system originated at the company's Napolean, Ohio plant in the early 1950's when an experimental spray irrigation site failed and overflowed its boundaries. The overflow runoff was found to exhibit 90 percent reduction of BOD (78). This resulted in the design of the Paris, Texas plant which was built in 1964.

Flow plots 61 to 91 meters in length (200 to 300 feet) with slopes of 1 to 12 percent receive 5 to 13 cm (2-5 inches) of wastewater per week (78). The daily application schedule is eight hours application, sixteen hours drying during dry months and six hours application, eighteen hours drying during humid months (44).

Only two effluent samples in five years have exceeded 10 mg/l BOD. No decreased performance during cold months was noticed. This phenomenon was ascribed to drastic increases in the microbiological population when activity per organism decreases due to cooler temperatures (24). The concentration of mineral salts in the groundwater has increased, but appear to be leveling off at a noncritical level (78).

A water balance study showed about 30 percent of the water treated on an annual basis to be rainwater. Evaporation accounted for 18 percent of the total flow, percolation another 21 percent and the remaining 61 percent was runoff to surface waters (44).

Results and recommendations from the Paris, Texas study include the following: (78)

1) 61 to 91 meter (200-300) foot plot length can be significantly reduced without lowering efficiency.

2) 1 to 12 percent slopes were used, 2 to 6 percent are recommended.

3) Additional land capacity for winter months is not necessary.

4) Application of 5 to 13 cm (2-5 inches) per week can be increased.

5) Nutrient removal can be increased over the original reported values.

The Corps of Engineers set up a scale model overland flow plot to study nitrogen removal. The plot lengths were 3 meters (ten feet) and the study lasted for twelve weeks. Total nitrogen removal was 82 percent. The crop tissue uptake accounted for 92 percent of the nitrogen removed, gaseous loss through denitrification was 7 percent, and less than 1 percent was retained in the soil. The conclusion was reached that phosphorus removal may be the critical limitation for overland flow (10,30).

Treatment Mechanisms

In view of the extremely high removal efficiencies and absence of sophisticated equipment and controls, overland flow seems amazingly efficient. Further study reveals, however, that overland flow utilizes most of the processes of modern secondary and tertiary treatment schemes in a natural manner.

The fate of the pollutant parameters of usual concern in domestic wastewaters may be traced. Organics in the particulate form are removed by sedimentation on the soil where they are metabolized along with soluble organics by the microflora populations. The resulting biomass is digested by other microorganisms with any non-biodegradable cell debris adding to the humus layer of the soil (49). The number of pathogens, including viruses, and coliform bacteria are reduced by desiccation and ultraviolet radiation (49).

Nutrients of concern are primarily nitrogen and phosphorus compounds. Nitrogen is in part removed by cover crop uptake, but aerobic microorganisms must first convert organic nitrogen to nitrates or ammonia. Some nitrogen is liberated in the gaseous state due to denitrification, an anaerobic microbial process. Very little added nitrogen remains in the soil (30).

Phosphorus can be adsorbed by clay particles. Some phosphorus is also removed by plant uptake (10).

Heavy metals are deposited in the soil by chemical precipitation as pH controls the metal solubility. The higher the pH, the less soluble are most metals. Soil absorption of CO_2, abundant due to decomposition of organics, provides buffer capacity and helps maintain near neutral pH values. The neutral pH not only promotes metal precipitation but favors cover crop growth and microbial activity (44).

The only readily available reports in 1976 upon which to base system design were the results from the Paris, Texas facility of the Campbell Soup Company (23, 24, 44, 78) the experimental system at Ada, Oklahoma (76), and preliminary results from the Pauls Valley, Oklahoma system. Slope lengths ranged from 61 to 91 meters (200 to 300 feet) at Paris, Texas, 61 meters (200 feet) at Pauls Valley, and 36 meters (118 feet) at Ada. Both Paris and Ada reported better than 90% BOD removal, and preliminary results showed good removals at Pauls Valley. It was decided to design the slope length at 46 meters (150 feet) for lagoon effluent application and 50 meters (165 feet) for plots to receive comminuted raw sewage.

The percent grade in use varied from 2 percent and 4 percent at Ada, 2 percent and 3 percent at Pauls Valley, and from 1 to 12 percent at Paris. Based on results from those three systems and the topography at the proposed Easley, S. C. site, it was decided to design for 4 percent grade.

Hydraulic loading rate had been the usual design criterion for wastewater application at the three systems referred to above. Application of 5 to 12 centimeters (2 to 5 inches) per week at Paris was reported to result in effective treatment. The Ada system reported effective treatment at 5 to 10 centimeters (2 to 4 inches) per week. Preliminary information on the Pauls Valley system indicated that raw wastewater was applied at about 5 centimeters (2 inches) per week and lagoon effluent at about 10 to 12 centimeters (4 to 5 inches) per week.

Therefore it was decided to design the Easley system for 13 centimeters (5 inches) per week application of comminuted raw sewage and for a range of 10 centimeters (4 inches) to 20 centimeters (8 inches) per week of lagoon effluent. These seemed to be reasonable application rates based on the available information.

SECTION 2

CONCLUSIONS

FEASIBILITY

Overland flow was found successful in treating both comminuted raw sewage and facultative lagoon effluent. Both wastewaters were converted into effluents similar to or better than effluents from more traditional secondary treatment plants. Costs of construction of the Easley Overland Flow System are not directly comparable to costs for an operating facility since additional expense was incurred for research reasons. However, overland flow appears to be a cost effective method for many areas in terms of both construction and operating costs.

DESIGN

Better understanding has been gained of possible application methods, hydraulic loading rates, application cycles, required plot lengths and expected effluent quality.

The design parameters used gave reasonable results. Flow distances of 46 meters to 60 meters (150 to 165 feet) appear feasible for use in treating domestic wastewaters. All slopes were constructed at 4 percent grade, and this seemed to work well.

Hydraulic loading rates utilized ranged from 4 inches per week to 10 inches per week for lagoon effluent and from 5 inches per week to 10 inches per week for comminuted raw sewage. Better nitrogen removals from raw wastewater resulted from the lower loading rates, and better suspended solids removals from lagoon effluent resulted from the lower loading rates. BOD removals were consistent at all loading rates studied.

SECTION 3

RECOMMENDATIONS

Additional work with overland flow for treating domestic wastewater is needed in order to develop rational design equations. Plots to be used for this research should have provision for careful measurement of influent and effluent volumes. Samples should be collected at short intervals down the plot in order to relate removal of various parameters to flow distance. Additionally, provisions should be made for varying the application rate from about 5 cm (2 inches) per week up to 40 cm (16 inches) per week in order to define the upper limits of the hydraulic loading rate. Both comminuted raw sewage and facultative pond effluent should be tested in this way.

Investigations of factors affecting removal of algal cells are also needed. The greatest immediate application of overland flow for treating domestic sewage is probably for improving the quality of effluent from existing facultative lagoons. Improvement in removing algal solids is needed for this application.

Operating data from a system with plot slopes less than 2% are needed. Numerous potential sites exist where earth moving costs are considerably increased if 2% is the least slope providing successful treatment. Extreme care in site preparation could possibly avoid problems due to or caused by ponding if efficient treatment could be achieved with slopes as low as 1%. The 4 percent grade used at Easley gave good results. Therefore, the often quoted range of slopes from 2 percent to 6 percent still seems reasonable for design use. From 30 to 61 meters (100 to 200) feet seems a reasonable slope length or flow distance based on the experience at Easley.

Hydraulic loading rates in the range of 7.6 to 25 centimeters (3 to 10 inches) per week for raw sewage and 10 to 30 centimeters (4 to 12 inches) per week for lagoon effluent should be used in designing overland flow systems for typical domestic wastewater. Site specific conditions will dictate which end of these ranges should be chosen.

An operating schedule of eight hours per day, 5 days per week gave satisfactory results at Easley. There appears no reason that operating 7 days per week should not give equally good results. A schedule of operating 8 to 12 hours per day, 5-7 days per week should be used in designing overland flow systems for domestic sewage treatment.

Storage should be provided even in mild climates for emergency periods, mowing and harvesting of grass, and short periods of severe weather.

SECTION 4

EXPERIMENTAL PROCEDURES

SITE SELECTION

A detailed procedure was developed for selecting the site to be used for this project. Only a summary is included here.

Constraints on sites selection included:

1. Existing sewage collection system
2. Average daily flow of sewage of approximately 380 cubic meters (100,000 gallons) per day
3. An existing facultative lagoon
4. Sufficient land available near the lagoon
5. Reasonable site topography to minimize earthwork
6. Reasonably impermeable soil at proposed site
7. Located within 48 kilometers (thirty miles) of Clemson University

After all sites within 48 kilometers (thirty miles) of Clemson University were inspected and rated by a numerical weighting system, the Golden Creek Lagoon site near Easley, S.C. was chosen for this project. The Easley Combined Utility System agreed to cooperate and shortly obtained 8 hectares (20 acres) of suitable land.

Specific design criteria for the site were then developed and are included in the following section of this report.

DESIGN CRITERIA

Raw Sewage System

Two separate treatment trains were designed for the Easley project. One system was designed to intercept raw sewage from the main sewer to the lagoon, screen and comminute the raw sewage and pump the comminuted sewage to three plots. The second system was designed to pump lagoon effluent from

the lagoon and distribute it to the ten plots intended to treat lagoon effluent. Four spare plots were reserved for use during down time for mowing grass or for high flow situations. Figure 1 shows the layout of the overland flow facility and its relationship to the lagoon and sewer line.

Raw sewage was intercepted from the main sewer which crossed the property acquired for the overload flow project. Manual stop gates were used to divert the flow to the pump station or to shut off the flow into the pump station and transmit the total flow to the lagoon. The raw sewage passed through a 3.2 cm (1 1/4 inch) bar screen, was shredded by a 0.6 cm (1/4 inch) comminutor, and was pumped to the raw sewage plots by a 3730 watt (5 horsepower) submersible centrifugal pump. Pump operation was controlled by a float activated switch in the pump well.

The raw sewage plots were 33.5 meters wide by 50.3 meters long (110 feet wide by 165 feet long) and each plot originally received raw sewage at the same nominal application rate of 118 liters per minute (31.1 gpm) for 6 hours per day, 5 days per week. The spray nozzles initially used clogged frequently and an application trough made of PVC pipe into which 22 five cm (two inch) slots were cut was used to provide uniform distribution of comminuted sewage across the width of each plot. A gate valve located in the feeder pipe to each plot was used to adjust the application rate. Application duration was controlled by the manual placement and removal of the stop gates for intercepting the main sewer.

Lagoon Effluent System

Two pumps, each powered by 5600 watt (7.5 hp) electric motors were located at a pump station at the lagoon to distribute lagoon effluent to the plots. Ordinarily only one pump was operated with the other serving as standby. Automatic control of the pumping cycle is controlled by a seven-day electric clock. Solenoid valves on each lateral pipe serving the lagoon plots were controlled by reset timers which were adjusted for the desired application duration and sequence. Effluent was applied to each plot from a row of six risers fitted with low pressure fan spray nozzles, sized to provide uniform distribution across the plots. Lagoon plots were 30.5 meters wide by 46 meters long (100 feet by 150 feet).

Earthwork

All plots were graded by motor grader to a nominal slope of four percent. The plots were seeded with Kentucky 31 Tall Fescue with rye added to help stabilize the plots during establishment of the fescue. All finishing and seeding operations were done across the slopes. Fertilizer and lime were added to the plots at twice the rate recommended for establishing fescue pastures. A 60 degree V-notch weir was placed at the toe of each slope to allow gaging of the total plot runoff.

A collection channel received the runoff from each plot. These collection channels join to form a main discharge channel which conveyed the

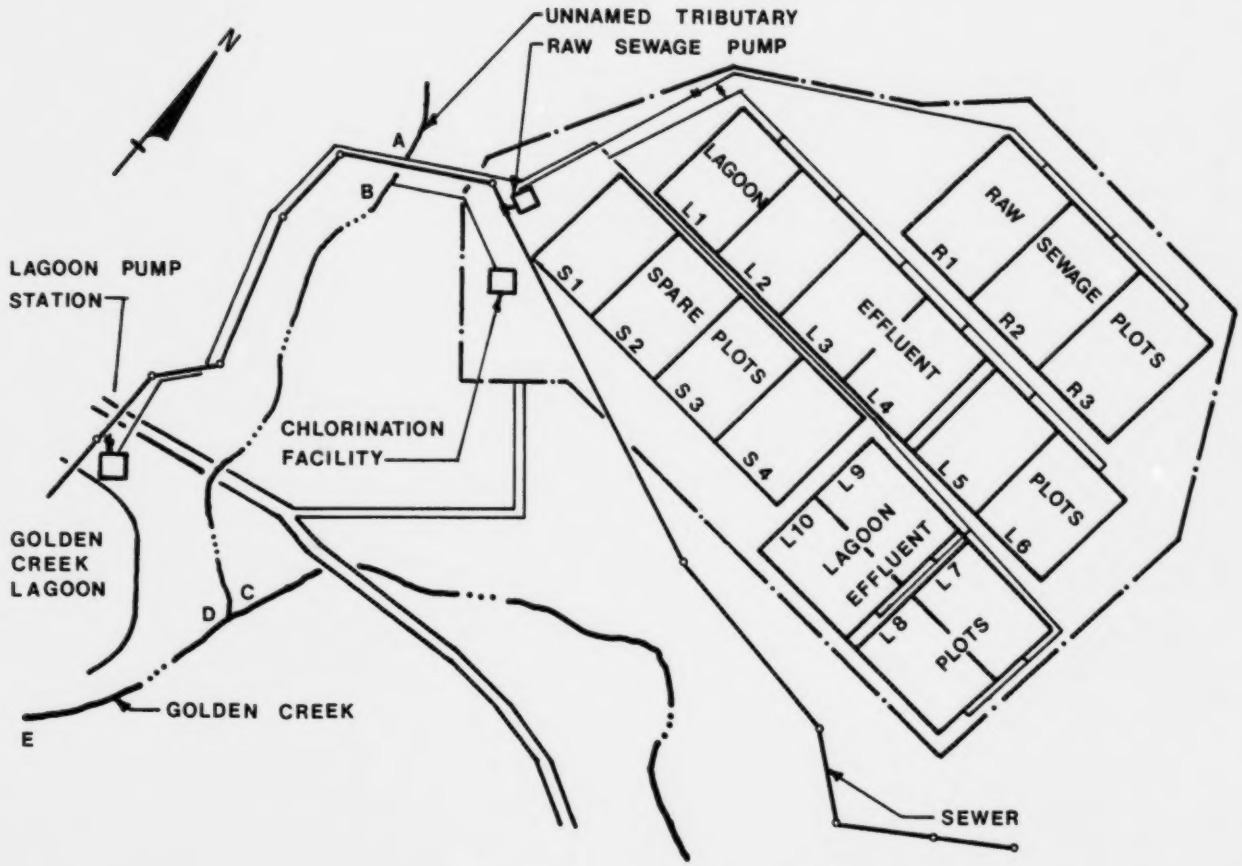

Figure 1. Easley, SC, Overland Flow System Layout

runoff to a chlorine contact chamber for disinfection. The total flow from the system is then measured through a Parshall flume before discharge into a small unnamed tributary approximately 230 meters (250 yards) upstream of Golden Creek.

Grading and grassing of the site was delayed by inclement weather, including heavy rainfall which caused severe erosion. Hand leveling and reseeding were necessary. Problems with establishing the cover crop and late delivery of pumps delayed system startup from August 1978 until January 1979.

PROJECT OPERATION

Operation of the Easley Overland flow system was based on two parameters; influent application rate and duration. This constrasts with the usual design parameter of surface loading. Application rate (liters per second or gallons per minute) and duration (hours) were used to simplify operation. However, surface loading rates can be computed for all operating periods and are presented for most cases.

The period from January 1979 until July 1979 was considered a start-up period. Results obtained during that period were influenced by poor cover crop conditions and lack of acclimated biota. Therefore, the early data were kept separate from the later results. Data collected from July 1979 through October 1979 were analyzed together as Study Period I, while results from the period February 1980 through May 1980 were treated as a cold weather period.

Phase 1

Three major operating schedules were tested at this project. The first schedule was used from January 1979 through May 1980. The application rates and frequencies for this period are shown in Table 1, and the operating sequence is contained in Table 2. The lagoon plots received nine combinations of application rate and application frequency with one combination replicated. The combinations were based on a statistical design to allow independent analysis of the effects of application rate and frequency on treatment efficiency.

During Phase one (January 1979 - May 1980) the raw sewage plots received comminuted raw sewage at the nominal rate of 117 liters per minute (31 gpm) for approximately six hours per day, five days per week. Raw sewage was actually supplied an average of 30 minutes per hour due to pump cycling controlled by the float switch in the wet well. These short cycles were necessary to avoid agglomeration of the solids in the comminuted raw sewage into a sludge which could not be successfully pumped by the available equipment.

TABLE 1

DESIGN APPLICATION RATES AND FREQUENCIES -- PHASE I

Wastewater	Design Flow (Based on 7-day week)		Operation	Applied Flow (Based on 5-day week)	
	gpd	gpw	(Days/Week)	gpd	gpw
Raw Sewage	24,000	168,000	5	33,600	168,000
Lagoon Effluent	76,000	532,000	5	106,400	532,000
TOTAL	100,000	700,000		140,000	700,000

Plot	Waste-water	Application Time (hrs)	Application Rate (gpm)	Volume Applied Per Day (gallons)	Areal Loading Rate (in/day)	(in/wk)
R1	Raw	6	31.11	11,200	0.93	4.67
R2	Raw	6	31.11	11,200	0.93	4.67
R3	Raw	6	31.11	11,200	0.93	4.67
L1	Lagoon Effluent	7	19.33	8,119	0.87	4.06
L2	Lagoon Effluent	7	25.33	10,639	1.14	5.69
L3	Lagoon Effluent	8	29.99	14,395	1.52	7.60
L4	Lagoon Effluent	7	25.33	10,639	1.14	5.69
L5	Lagoon Effluent	6	29.90	10,764	1.15	5.76
L6	Lagoon Effluent	7	31.33	13,159	1.41	7.04
L7	Lagoon Effluent	5.5	25.33	8,359	0.89	4.47
L8	Lagoon Effluent	8.5	25.33	12,918	1.38	6.91
L9	Lagoon Effluent	6	21.10	7,596	0.81	4.06
L10	Lagoon Effluent	8	21.10	10,128	1.08	5.42
S1 through S4 - Spare Plots						

TABLE 2

OPERATING SEQUENCE

Raw Sewage Application

93.3 gpm, 6 hrs/day, 5 days/wk

0800			1200			1600				2000						2400				0400				0800	Time
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		Hours
R1																									
R2																									
R3																									

Lagoon Effluent Application

127 gpm, 14 hrs/day, 5 days/wk

0800				1200				1600				2000						2400				0400				0800	Time
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			Hours
L7						L8																				
L9						L10																				
L5						L3																				
L2						L6																				
L4						L1																				

Phase 2 Operation

Phase two began in June 1980 and continued through August 1980. Table 3 shows the schedule during this period. Only four lagoon plots and two raw plots received wastewater applications in order to increase the loading rates in an attempt to stress the system. This was attempted in order to assess upper limits of hydraulic or organic loading rates at which effective treatment could still be achieved.

Phase 3 Operation

From September 1980 until the end of the project in November 1981 the raw sewage system, was not operated, and wastewater was applied only to the ten lagoon effluent plots by pumping from the lagoon.

The operating schedule was 14 hours per day, 5 days per week during this period of operating the lagoon system only. The operating day was extended to allow application of the total flow received by the lagoon without using the raw sewage system. This should have resulted in approximately 3.6 cm per day (1.4 in/day) hydraulic loading rate. Table 4 contains the design rates for Phase III.

Sampling Methods

After consultation with EPA personnel it was decided that grab samples would be sufficient for most of the liquid sampling work. Grab samples were collected in carefully cleaned polyethylene bottles and transported to Clemson for analysis in the laboratories of the Environmental Systems Engineering Department. Sterile glass containers were used for collecting samples for bacteriological analyses.

Samples for characterizing the raw sewage were collected twice monthly from the distribution system just before application to the plots. Samples from Golden Creek were hand collected as described in "Standard Methods" (3).

Plot effluent samples were collected at the V-notch weirs that were also used to gage the volumetric flow rate. Total system effluent samples were collected just downstream of the chlorine contact chamber except for samples for bacteriological analyses which were collected just upstream of the chlorine contact chamber (without disinfection) or just before the discharge entered the receiving stream (disinfected samples) (7).

Samples for profile studies on the raw sewage plots were collected at distances of 7.6, 15, 23, 30, and 41 meters (25, 50, 75, 100, and 135 feet) downslope from the point of application. These samples were originally collected manually using a 50 ml beaker by compositing portions over the width of the plot to reach a volume of one liter. Later, 250 ml plastic beakers were embedded in the plot turf with the lip of the beaker approximately level with the soil surface. These beakers were left in

Table 3

OPERATION SCHEDULE FOR EASLEY OVERLAND
FLOW SYSTEM -- PHASE II

Wastewater	Design Flow (Based on 7-day wk)		Operation (days.week)	Applied Flow (Based on 5-day wk)	
	gpd	gpw		gpd	gpw
Raw Sewage	23,100	162,000	5	32,400	162,000
Lagoon Effluent	72,000	504,000	5	100,800	504,000
Total	95,100	666,000	---	133,200	666,000

Plot	Wastewater	Application Time (hrs)	Application Rate (gpm)	Volume Applied Per Day (gals)	Areal Loading Rate (in/day)	Areal Loading Rate (in/wk)
R2	Raw Sewage	6	90	32,400	2.86	14.30
L1	Lagoon Effluent	8	80	38,400	4.11	20.55
L2	Lagoon Effluent	6	80	28,800	3.08	15.40
L3	Lagoon Effluent	8	40	19,200	2.05	10.25
L4	Lagoon Effluent	6	40	14,400	1.54	7.70

TABLE 4

OPERATION SCHEDULE FOR EASLEY OVERLAND FLOW SYSTEM -- PHASE III

Wastewater	Design Flow (Based on 7-day wk.		Operation (days.week)	Applied Flow (Based on 5-day wk)	
	gpd	gpw		gpd	gpw
Raw Sewage	0	0	0	0	0
Lagoon Effluent	95,100	666,000	5	133,200	666,000

Plot	Wastewater	Application Time (hrs)	Application Rate (gpm)	Volume Applied Per Day (gals)	Aerial Loading Rate (in/day)	Aerial Loading Rate (in/wk)
L1	Lagoon Effluent	14	16	13,320	1.4	7.0
L2	Lagoon Effluent	14	16	12,320	1.4	7.0
L3	Lagoon Effluent	14	16	13,320	1.4	7.0
L4	Lagoon Effluent	14	16	13,320	1.4	7.0
L5	Lagoon Effluent	14	16	13,320	1.4	7.0
L6	Lagoon Effluent	14	16	13,320	1.4	7.0
L7	Lagoon Effluent	14	16	13,320	1.4	7.0
L8	Lagoon Effluent	14	16	13,320	1.4	7.0
L9	Lagoon Effluent	14	16	13,320	1.4	7.0
L10	Lagoon Effluent	14	16	13,320	1.4	7.0

place. Before sample collection the beakers were emptied using a hand vacuum pump and wiped out. About an hour later the vacuum pump was again used to pull the liquid from the collection beakers for compositing in a one liter sample bottle. At times it appeared that local movements of solids occurred which added large amounts of particulate material to the collection beakers. Neither method of collecting samples for profile studies was entirely satisfactory. Some measure of subjectivity was added when subsamples were selected for inclusion in or rejection from the composite sample.

Influent samples of lagoon effluent were collected at the distribution system just before application to the plots. Plot runoff was collected at the V-notch weirs just as for the raw plot runoff samples. Profile samples for the lagoon plots were collected in a manner identical for the raw plots except the intervals were (7.6, 15, 23, 30, and 38 meters (25, 50, 75, 100, and 125 feet).

Aerosol Sampling Procedure

Air sampling was conducted to estimate the input of viable bacteria into the atmosphere with aerosols formed during wastewater application. An Andersen two-stage impactor was used for aerosol sampling in conjunction with nutrient agar plates for enumerating aerobic heterotrophic bacteria and with endo agar plates for enumerating total coliform numbers (4). The agar media were prepared and the plates were incubated as directed in "Standard methods" (3).

Aerosol samples were collected at approximately one meter above the soil surface both upwind and downwind of the spray risers operating on lagoon effluent plots at distances of 31 meters upwind and 1.5, 9.0, 18, and 31 meters downwind of the nearest spray risers.

ANALYSES

Biochemical oxygen demand (BOD), suspended solids, total organic carbon (TOC) or chemical oxygen demand (COD), total phosphorus, and total nitrogen have been used as key parameters for monitoring treatment efficiency in land treatment systems (76, 77, 73, 78, 65, 44, 30, 23, 24). These measurements were used along with the other analyses listed in Table 5. These parameters served to characterize the solids content, oxygen demand and nutrient content of the wastewater before and after treatment. Ground-water tests included chloride and nitrate analyses as well as bacteriological tests (3, 16).

Biochemical Oxygen Demand

Biochemical oxygen demand is one of the more traditional wastewater parameters. Most of the standards on record are written in terms of BOD. This fact in itself requires that BOD be included in this study. The BOD test is used as an estimate of the oxygen utilized during aerobic

TABLE 5

PARAMETERS MONITORED AT THE EASLEY OVERLAND FLOW PROJECT

Biochemical Oxygen Demand - BOD_5
- Soluble BOD
- Particulate BOD

Total Organic Carbon - TOC
- Soluble TOC
- Particulate TOC

Specific Conductance - Cond.

Suspended Solids - SS

Orthophosphate - $O\text{-}PO_4$

Total Phosphorus - TP

Total Kjeldahl Nitrogen - TKN

Ammonia Nitrogen - NH_3 - N

Nitrate plus Nitrite Nitrogen - $NO_2 + NO_3$ - N

Dissolved Oxygen - DO

pH

Bacterial Enumeration
- Total coliform numbers
- Fecal coliform numbers
- Fecal streptococcus numbers
- Aerobic heterotrophic bacteria

stabilization of the organic matter in a liquid sample. Dilution and incubation procedures used were taken from "Standard Methods" (3). Filtration of subsamples through Whatman GF/C glass fiber filters was used to prepare the subsamples for soluble BOD determinations. The difference between unfiltered and filtered subsamples was reported as "particulate BOD."

Total Organic Carbon

Total organic carbon (TOC) is a measure of the concentration of organic matter in the wastewater being analyzed (53). It is especially applicable to cases where only a small amount of organics are expected. The significant factor about TOC is that it is a direct measure of the organic matter present in the sample. The main factors considered in the decision to use TOC over COD were the time, reproducibility, and sensitivity of the analysis.

In the TOC analysis, the organic carbon in a sample is converted to carbon dioxide (CO_2) by chemical oxidation. The carbon dioxide formed is measured in an infrared spectrophotometer. The amount of carbon dioxide detected is directly proportional to the amount of carbonaceous material present in the sample if inorganic carbon is removed by pretreatment (3). Filtration of subsamples through Whatman GF/C glass fiber filters was also used to separate "soluble TOC" from "particulate TOC."

Solids

An important physical characteristic of wastewater is its total solids content (51). Total solids are composed of dissolved solids and suspended solids. Suspended, or nonfilterable, solids are defined as those solids which are retained by a standard filter and dried to constant weight. Those solids which passed through the filter are termed filterable or dissolved solids. Both suspended and dissolved solids are important in overland flow, although in different ways.

Phosphorus

Nitrogen and phosphorus are both essential for the growth of green plants, and limitations in the amounts of these elements are usually factors which control their growth (63). Phosphorus could be the most limiting nutrient in the aquatic ecosystem simply because it is one of the nutrients which is least abundant in our waters.

Generally, with overland flow runoff, the major form of phosphorus of concern would be total phosphorus concentration (59). Orthophosphate was also measured on most samples analyzed for the project. Samples were not filtered.

The EPA recommended ascorbic acid reduction method was used in this study. The procedure is outlined in Stand Methods (3).

Nitrogen

Nitrogen is important for the growth of all organisms (51). It is used for protein production and cellular repair. Most plants require nitrogen to be in the form of nitrate or ammonia.

Total Kjeldahl nitrogen was determined by a modified procedure developed by Gales (19). This method has a range of 0.1 to 20 mg N/l which can be extended by dilution.

Ammonia was determined with a specific ion electrode. The Orion Model 95-10 electrode allows a range of 10^{-6} M to 1 M (54). This translates to 0.02 mg/l - 20 mg/l, which adequately covers the range of expected values, and which can be expanded by dilution if needed.

Two procedures were available for nitrate and nitrite determinations. One method is use of a selective ion electrode such as the Orion Model 92-07. The other procedure is a colorimetric determination following the passage of the sample through a cadmium reduction column. The Orion electrode has a range of 0.62 mg/l (10^{-5}M) to 62.0 mg/l (10^{-1}M) (54). The cadmium reduction method has a range of 0.01 - 1.00 mg/l that can be extended by dilution (16). Both methods were used in this project. The specific ion electrode method worked well for samples treated by overland flow, but it was not satisfactory for samples of raw sewage or lagoon effluent. The cadmium reduction method was applicable to all samples on which it was tried.

Measurement of total Kjeldahl nitrogen (TKN), ammonia nitrogen, and and nitrate nitrogen were made from the start-up of the project. However, early measurements of TKN were made using a heated block digester. Upon running samples spiked with known amounts of organic nitrogen it was discovered that incomplete digestion was occurring and recovery was not complete. After August 1, 1979 all samples for TKN were digested using 100 ml Kjeldahl flasks, which procedure resulted in complete recovery of spikes and much better precision than the block digestor procedure (3, 16).

Early measurements of raw sewage and lagoon effluent samples were attempted using an Orion nitrate probe and specific on meter (54). The results were unbelievably high for the raw sewage samples. It was found that interferences in raw sewage and lagoon effluent resulted in erratic readings for these samples. Therefore, the cadmium reduction/colorimetric method was substituted for nitrate plus nitrite analyses for raw sewage samples and lagoon effluent samples after January 1, 1980 (3, 19, 16). The cadmium reduction/colorimetric method was used for all nitrate measurements after July 1, 1980. The earlier, questionable measurements are not included in this report.

Dissolved Oxygen

Oxygen is important because most living organisms are dependent on it. Aquatic organisms are no exception to this fact, and they must obtain their oxygen supply from that dissolved in the water. Dissolved oxygen was measured with a Model 54 DO meter by Yellow Springs Instrument Co.

pH

A Corning Model 12 Research pH meter was used for pH measurements in this project. The pH measurements were made as soon as possible after samples were transported to Clemson.

Specific Conductance

Specific conductance is useful for measuring the ability of a solution to conduct electricity, a property proportional to the concentration of dissolved, ionized materials. Although a nonspecific test, it can be used to estimate effects of treatment upon the dissolved material present in a wastewater. Procedures for measuring specific conductance are given in both Standard Methods (3) and the EPA Manual (16).

Chloride

Chloride ion concentrations in groundwater samples were measured using an Orion chloride electrode and Orion Model 901 Ionalyzer.

Microbiological Methods

The membrane filter technique was used for all waterborne bacteria analyses. With this method an appropriate volume of a water sample or a diluted water sample is passed through a membrane filter which retains the bacteria present in the sample. The filter with the bacteria is placed on an absorbent pad in a petri dish. The absorbent pad is saturated with a nutrient solution which is selective for the growth of certain bacteria. The dish is then inverted and placed in an incubator for incubation at the appropriate temperature and time period. After incubation, colonies are counted and converted to numbers per 100 ml (7).

Glassware was sterilized one day before sampling using a Castle Thermatic 60 autoclave set at 121°C and 15 psi for a sterilization time of 15 minutes. Glassware was wrapped in aluminum foil before sterilization, while dilution tubes were capped with autoclavable caps. Dilution water was buffered using phosphate and magnesium sulfate buffer solutions. The dilution water was placed in one liter polypropylene bottles and autoclaved along with the glassware.

Total coliform, fecal coliform, and fecal streptococci were analyzed at each sample location using M-Endo broth, M-FC broth, and KF-Streptococcal agar, respectively. Media were prepared one day before sampling and stored at 4°C until ready for use. Broth was stored in Erlenmeyer flasks, while the agar was poured into 50 x 9 mm petri dishes (3).

Dilutions were established by trial and error and ranged from 10 ml samples at the stream stations to 0.00001 ml samples at the raw sewage sample stations. Two dilutions were used for each of the stream sample stations, while three dilutions were used at each of the wastewater sample stations in order to obtain a countable number of colonies on the membrane filter. Duplicates were run for each type of test at each sample station.

Grab samples were collected at each sample station using sterile sample bottles. The water samples were put on ice and transported to the laboratory, and filtration was accomplished within six hours after sample collection.

Total coliforms were incubated for 20-24 hours at 35°C, while fecal coliforms were incubated for 20-24 hours at 44.5°C. Fecal streptococci were incubated for 48 hours at 35°C. After appropriate incubation, dishes were counted and converted to numbers per 100 ml of sample. The geometric means were calculated for each type of test at each sample station (3).

On two dates during the summer, sampling was conducted on plot R2, a raw sewage plot, in order to determine the reduction of bacteria as a function of distance down the plot. Samples were obtained from the same sampling cups used for other samples. Sterile plastic 50 ml syringes were used to collect a cross-sectional composite sample at each down-slope distance, as well as from the influent and effluent streams. These samples were examined for fecal coliforms and fecal streptococci only.

Air Sampling

Air samples were taken both upwind and downwind of spray risers which supplied treated wastewater plots at the overland flow project. Lagoon effluent spray risers were used because most aerosolization of bacteria occurs when wastewater is sprayed into the air.

The aerosol study was conducted on plots L7 - L10 (Figure 1). Total bacteria and total coliform numbers were measured at one upwind location and three downwind locations. The upwind station was established away from the influence of the lagoon and overland flow project. The downwind locations were established at distances of 9.1, 18.3, and 30.5 meters (30, 60, and 100 feet) downwind of the most downwind spray riser. During the last few months of sampling, a 1.5 meter (5 feet) downwind location was substituted for the 30.5 meter location in order to demonstrate higher numbers near the spray pattern. The procedure used was based upon the experience of Hall, et al. at Pauls Valley, Oklahoma (25).

Prevailing winds were normally from the southwest. However, both upwind and downwind sampling locations were based on actual wind direction on each sampling date.

A two stage Andersen impactor was used in the aerosol study (4) Petri dishes containing nutrient agar for total bacteria and M-Endo agar for total coliforms were placed in the impactor. The Andersen impactor is designed to separate the particles it collects into respirable and nonrespirable sizes. However, no consideration was given to particle size in this study.

The correct volume of air to sample was determined by trial and error, based on getting a countable, but not "overcrowded" number of colonies on the plates. Sample volumes actually used are given in Table 6. The Andersen sampler contains a critical orifice through which 28.32 liters (one cubic foot) of air passes per minute when vacuum applied is 36 cm of mercury or greater. The volume of air sampled was then easily determined from the amount of time the sampler was operated.

The upwind location was sampled first, while the spray risers were running on the plots. This procedure served to clear the pipelines of all

Table 6. SAMPLE VOLUMES (LITERS) USED IN AEROSOL STUDY

Test	Upwind	1.5 m	9.1 m	18.2	30.5 m
Total bacteria	141.5	28.3	141.5	141.5	141.5
Total coliforms	566.0	141.5	566.0	566.0	566.0

wastewater present while these plots were turned off. While sampling, the Andersen impactor was placed on a box, so that the sampler was elevated 38 cm above the ground. After sampling, the dishes were covered with their lids and placed inside an insulated box for protection against sunlight. Sampling then proceeded at the 9.1, 18.3, and 30.5 meter locations successively. Weather conditions on sampling days are included under results.

After sampling was completed, the innoculated dishes were brought to the laboratory and placed in an incubator for 24 hours at 35°C. After appropriate incubation, colonies were counted and converted to numbers per cubic meter.

An earlier plan of using M-Endo, M-FC and KF-Streptococcal agar at distances of 30.5, 91.4, and 304.8 meters (100, 300, and 1000 feet) downwind, as well as upwind, had to be aborted due to poor results. Early sampling results indicated that with this type of application, bacteria do not survive long enough to disperse to these distances, and that the media are too specific for countable growth at observed densities.

GROUNDWATER STUDY

Installation of Test Wells

Ten monitoring wells were installed with motor powered augers by personnel from the Environmental Systems Engineering Department and the Groundwater Protection Division of the S. C. Department of Health and Environmental Control. Each well was cased with 5 cm (2 inch) PVC pipe with slotted PVC well screens installed near the bottom of the casing. A detail of a typical monitoring well is shown in Figure 2.

Limited groundwater information led to the hypothesis that groundwater flow should be in a southwesterly direction. If this hypothesis were correct then wells number 1 and number 6 could serve as background or reference wells and the remaining wells would serve to show any contamination resulting from the overland flow system. Actual measurements to determine gradient are included with results.

Sampling Groundwater

The 5 cm (2 inch) casing limited the use of readily available submersible pumps and the depth to groundwater at some well sites limited

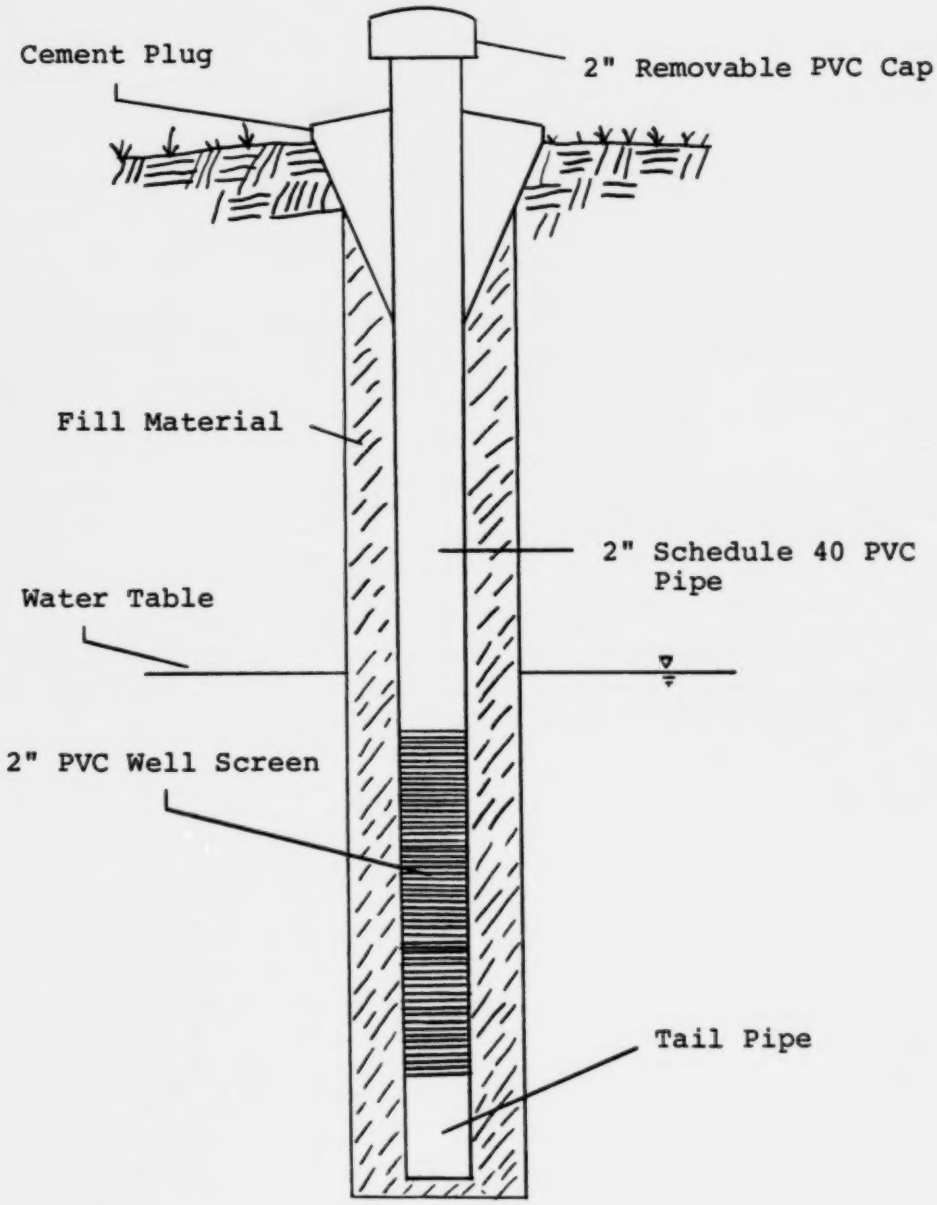

Figure 2. Typical Monitoring Well Construction Design

the use of lift pumps. Therefore two sampling techniques were utilized. A pneumatic pressure system was installed on wells 3, 6, and 8. This system was intended to avoid bacterial contamination during sampling. See drawing in Figure 3. The other wells were sampled with a bailer lowered and raised manually with a nylon line. The bailer was assembled from PVC pipe and fittings and a foot-valve.

Sampling Period

An intensive study of the effects of the overland flow system upon the underlying groundwater was carried out during the summer of 1981. At that time the overland flow system had been in operation more than two years.

Water Table Measurements

Water table elevations were measured using a cloth tape. Standard surveying techniques were used to determine the elevations of the top of each well casing. Depth to water was subtracted from the elevation of the well casing to give water table elevations.

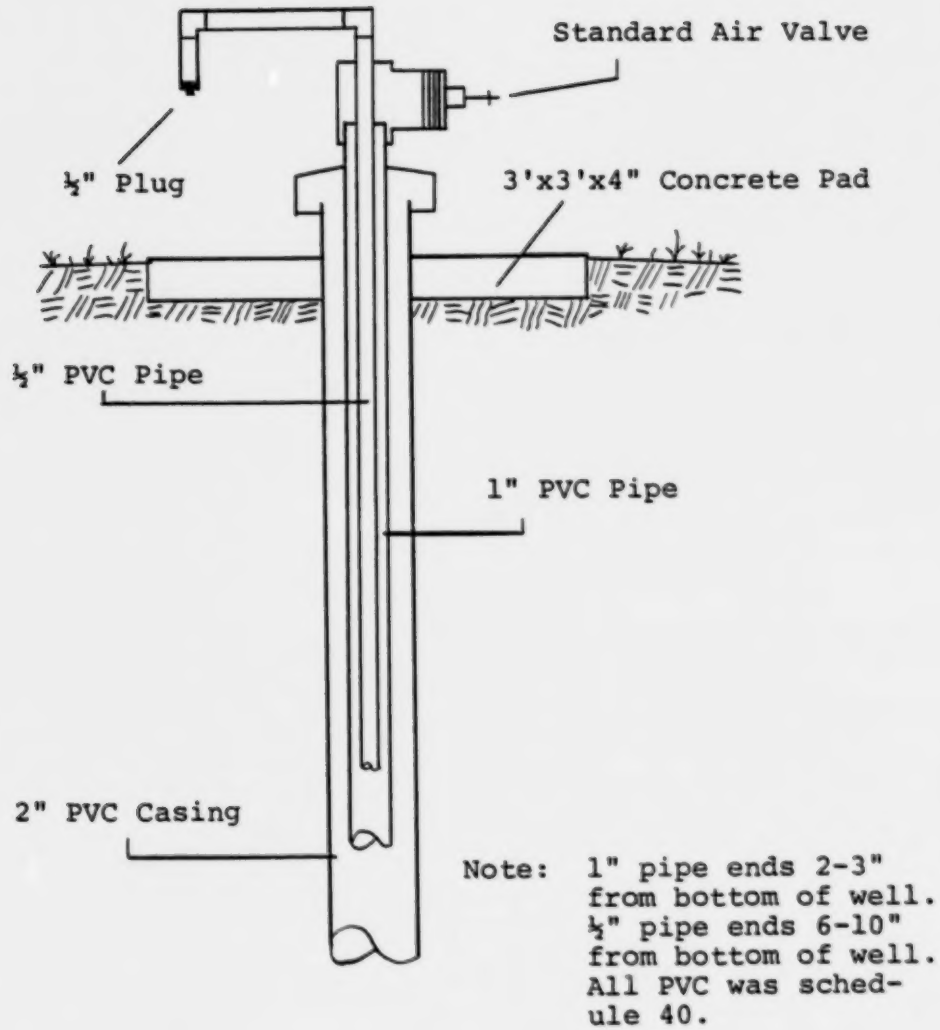
Standard Air Valve
½" Plug
3'x3'x4" Concrete Pad
½" PVC Pipe
1" PVC Pipe
2" PVC Casing
Note: 1" pipe ends 2-3" from bottom of well. ½" pipe ends 6-10" from bottom of well. All PVC was schedule 40.

Figure 3. Pumping System for Wells 3, 6, and 8

SECTION 5

RESULTS

CONSTRUCTION COSTS

Table 7 contains a summary of construction costs. Costs of site preparation and the mechanical, electrical and concrete contract were increased an estimated ten percent by research requirements. Without research objectives the facility could have been constructed for approximately $173,000.

Table 7. CONSTRUCTION COSTS

Land purchase, 20 acres	$ 40,000.00
Site preparation	34,940.00
Mechanical, electrical and concrete	83,832.00
Equipment	13,766.00
Engineering fees	12,000.00
TOTAL CONSTRUCTION COSTS	$184,538.00

OPERATING COSTS

Costs for operating the overload flow facility for a continuous, 12-month period are shown in Table 8. The research mission for the project probably required 1/4 time for the operator. Without research expenses the year's operating costs would have been approximately $6,425.00.

TABLE 8. OPERATING COSTS

12 months - August 1, 1979 to July 31, 1980

Electrical power	$ 754.00
Labor	
1/2 time for one operator	8,940.00
Mowing and grass removal (2 harvests)	500.00
Chemicals and supplies	490.00
TOTAL OPERATING COSTS	$10,684.00

START-UP EXPERIENCE

Construction of the Easley Overland Flow Facility proceeded during 1977 and 1978. The facility was essentially complete and ready for start-up in January 1979. However, the grass was not yet well established and considerable bare earth was still exposed on the plots. It was decided to check out all parts of the system with official start-up the first week in January. During the initial period application of wastewater was made only during the normal working day so that an operator could check on the equipment. This also minimized potential freezing problems, although three gate valves did fracture from freezing due to incomplete drainage.

Equipment Problems

The damage due to freezing led to the use of heat tape on piping at both pump stations. The decision was also made to enclose the lagoon pump station as soon as possible.

The lagoon effluent system incorporated solenoid valves at the laterals and reset timers at the pump station for automatic operation. Many of the solenoid valves failed because of flooding of the valve pits.

Application of lagoon effluent at the design rate was not possible until March 1, 1979. However, measurement of application rates in March indicated that design rates could not be achieved with the existing pumps and piping system.

Operation of the raw sewage system was shut down after two weeks because of almost continuous clogging problems in the spray nozzles and piping system. Settling of the comminuted solids in the raw sewage while in the wet well resulted in a heavy sludge which could not be pumped. Two measures corrected the situation. The float switch in the wet well was set to start the pump when the water level in the wet well reached about 38 cm (15 inches) above the empty level. This resulted in operation of the pump for about 10 minutes followed by about 10 minutes during which the pump was off. This sequence prevented the agglomeration of the sewage solids into a dense sludge. Also, a low pressure header was devised to distribute the wastewater across the head of the plot. PVC pipe (15 cm or 6 inch diam.) was used to construct a trough with 22 rectangular slots spaced evenly across the plot width. This avoided the plugging problems experienced with the spray nozzles. Together, these changes allowed successful operation of the raw sewage system after May, 1979.

The lagoon effluent system operated satisfactorily other than for problems of freezing and solenoid valve failure. The pump installed did not have capacity to deliver lagoon effluent at the rate desired, however. The lagoon system was placed under the automatic control system in mid-March 1979. Repetitive failures of solenoid valves plagued the system until most were replaced in May. Thereafter reasonable operation proceeded for the next 30 months. Clogging of the spray nozzles was not a major problem. Actual measurement of hydraulic application rates revealed that design rates were not achieved, however.

Measurement of the runoff at the V-notch weirs indicated that 70 per cent of the applied wastewater was recovered as runoff during March and April. Throughout the project period percent runoff was proportional to application rate.

Operation of the facility during the early months resulted in some erosion of the bare soil areas and an effluent containing some suspended solids from the eroded soil particles. After the spring growing season began in March, the added wastewater encouraged rapid growth of the fescue, and hand work of leveling and reseeding led to the establishment of a fairly complete cover crop. After these improvements in the plots the suspended solids concentrations declined in both the effluent from the plots receiving raw sewage and the effluent from the plots receiving lagoon effluent. BOD concentrations appeared to decline also.

TREATMENT OF RAW SEWAGE

As outlined under project operation in Section 4, the raw sewage system was operated according to two loading rates and schedules. From January 1979 through May 1980 raw sewage was pumped to the plots approximately six hours per day. Hydraulic loading varied from plot to plot and from day to day. The average daily application was 31,415 liters per day (8,300 gallons per day) per plot for a total raw sewage volume treated per day of 94,300 liters (24,900 gallons).

Phase I

For data analysis Phase I was divided into three periods -- Startup Period (January 1979 - May 1979), Intensive Study Period I (July 1979 - October 1979), and Cold Weather Monitoring Period I (February 1980 - May 1980). During Phase I the raw sewage BOD_5 varied from 90-270 mg/l with an overall mean of 165 mg/l.

Table 9 contains the data collected on the raw sewage plots during startup. The plots were improving in cover crop density during this period and were becoming acclimated to the wastewater application. Yet the plots were more effective in removing BOD_5 than lagoon treatment alone.

Table 10 displays the results from the raw sewage plots during the period from July 1979 through October 1979, a period in which the cover crop was well established and the mechanical system for handling raw sewage was operating reasonably well. The mean BOD_5 for the raw sewage plot effluent was 24 mg/l during that time, a reduction of about 87%. Note that the mean concentration of suspended solids in the effluent was 11 mg/l, a reduction of about 92 percent. During this period it became obvious that the overland flow plots could do a good job of treating comminuted raw sewage.

The first period of cold weather operations produced the data summarized in Table 11. In spite of lower temperatures the overland flow plots reduced the BOD_5 from a mean of 124 mg/l to a mean concentration of

TABLE 9 : Performance of Raw Sewage Plots During Phase I--Startup Period (January 1979 through May 1979)

Parameter	Raw Sewage			Average Raw Sewage Plot Effluent			
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)
Biochemical Oxygen Demand	167	90-270	16	25	3-50	7	85.0
Soluble BOD	58	35-93	10	20	3-35	6	65.5
Particulate BOD	109	50-212	10	5	-	0	95.4
Suspended Solids	151	52-464	17	41	12-122	10	72.9
Volatile Suspended Solids	137	40-384	13	41	12-22	3	70.1
Soluble Organic Carbon	29	10-57	14	19	7-26	9	34.5
Total Phosphorus (as P)	5.9	1.0-11.9	8	3.5	0.5-5.1	7	40.7
Ortho Phosphate (as P)	4.9	2.6-9.6	10	3.5	2.4-4.3	7	28.6
Total Kjeldahl Nitrogen (as N)	19.3	12.6-32.9	4	-	-	0	-
Ammonia Nitrogen (as N)	11.8	3.57-24.5	14	2.27	0.70-8.40	9	80.8

TABLE 10: Performance of Raw Sewage Plots During Phase I--Study Period I (July 1979 through October 1979)

Parameter	Raw Sewage			Average Raw Sewage Plot Effluent			
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)
Biochemical Oxygen Demand	183	108-258	9	24	13-23	10	86.9
Soluble BOD	54	25-69	5	8	3-15	9	85.2
Particulate BOD	129	83-159	4	16	11-22	7	86.8
Suspended Solids	136	40-380	8	11	2-38	20	91.9
Volatile Suspended Solids	120	34-334	8	8	2-20	20	93.3
Total Organic Carbon	92	44-204	11	34	21-46	21	63.0
Soluble Organic Carbon	36	23-58	10	24	13-32	21	33.3
Particulate Organic Carbon	56	16-158	10	10	2-20	21	82.1
Total Phosphorus (as P)	10.7	4.7-17.7	10	4.2	1.4-8.0	21	60.8
Ortho Phosphate (as P)	7.9	3.9-11.7	10	3.7	1.8-7.6	22	53.2
Total Nitrogen (as N)	-	-	0	8.41	3.73-13.1	14	-
Total Kjeldahl Nitrogen (as N)	26.3	15.6-40.6	12	6.37	2.66-12.1	23	75.8
Ammonia Nitrogen (as N)	14.4	9.52-26.5	12	2.86	0.04-8.94	24	80.1
Nitrate Nitrogen (as N)	-	-	0	1.52	0.59-3.36	15	-
Nitrite Nitrogen (as N)	0.73	0.06-2.31	9	0.18	0.02-0.57	20	75.3

TABLE 11: Performance of Raw Sewage Plots During Phase I--Cold Weather Monitoring Period I (February 1980 through May 1980)

Parameter	Raw Sewage			Average Raw Sewage Plot Effluent				
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)	Mass Removal (%)
Biochemical Oxygen Demand	124	62-177	6	19	15-26	12	84.7	90.8
Soluble BOD	45	37-59	6	7	5-10	14	84.4	90.7
Particulate BOD	79	22-118	6	12	6-16	12	84.8	90.9
Suspended Solids	122	93-154	8	31	14-73	16	74.6	84.7
Volatile Suspended Solids	103	80-136	8	24	9-42	16	76.7	86.0
Total Organic Carbon	95	67-130	8	38	20-47	15	60.0	76.0
Soluble Organic Carbon	42	30-91	8	30	14-41	15	28.6	57.1
Particulate Organic Carbon	53	36-92	8	8	2-17	15	84.9	90.9
Total Phosphorus (as P)	5.2	3.2-8.1	2	4.7	-	2	9.6	45.7
Ortho Phosphate (as P)	3.1	1.9-4.8	2	3.1	-	2	0.0	39.9
Total Nitrogen (as N)	-	-	0	19.2	2.83-43.7	9	-	-
Total Kjeldahl Nitrogen (as N)	53.7	22.1-117.0	3	18.2	2.55-42.7	9	66.1	79.6
Ammonia Nitrogen (as N)	45.3	14.0-136.0	5	<3.09	<0.14-13.1	12	>93.2	>95.9
Nitrate Nitrogen (as N)	-	-	0	<0.91	<0.14-2.01	13	-	-
Nitrite Nitrogen (as N)	0.36	0.18-0.66	6	0.50	0.14-1.81	14	<-38.9	>16.5

19 mg/l, a removal of 85 percent. Suspended solids in the effluent resulted in a mean concentration of 31 mg/l with the increase probably due in part to increased rainfall and the resulting transport of more particles from the plots.

Table 12 contains a summary of the performance of the raw sewage plots during Phase I. It may be seen from these data that the average performance of the raw sewage plots met secondary effluent standards with significant removals of nitrogen compounds and phosphorus compounds. The peak values shown for the parameter ranges almost all occurred during startup when operation was intermittent and the plots not yet acclimated.

Measurement of actual application rates and runoff from the raw sewage plots during January 1980 indicated that the plots were not receiving the design hydraulic loading and that hydraulic recovery averaged 62 percent during this cold, wet period. If the concentration removals shown in Table 12 were calculated on the basis of mass removal, removal efficiency would be considerably increased.

Phase II

A second operating schedule was implemented for Phase II in order to hydraulically stress the overland flow system. In June 1980 the system was put in operation according to the schedule shown in Table 3 (page 14). This schedule was in use through August, 1980. Unfortunately, the actual rates of application varied considerably from the intended rates. There were operational difficulties with the pumping system, and the unusually hot, dry summer resulted in low sewage flows and rapid lowering of the water level in the lagoon. Because of these problems actual application rates were lower than intended as can be seen in Table 13. Note that the limited availability of wastewater led to use of only four plots for treating lagoon effluent and two plots for treating raw sewage. Plot R-1, which received a nominal one inch per day hydraulic loading, had no observed runoff during this period. Therefore, all data reported for raw sewage treated by overland flow during the period resulted from Plot R-2.

The volume of wastewater applied to Plot R-2 and the volume of runoff from Plot R-2 were measured on fourteen different days during this period. The average daily hydraulic loading was 5.36 cm (2.11 inches) of comminuted raw sewage applied to the 89 percent of the plot which was found to be effectively wetted. Daily applications varied from 1.3 cm up to 11 cm (0.5 - 4.4 inches) of wastewater. See Table 14.

Of the applied wastewater the runoff for the measured 14 days of operation averaged 77.9% as can be seen in Table 14. Of the remainder approximately 19 percent was lost to evapotranspiration and 3.1 percent percolated into the groundwater. Potential evapotranspiration was calculated by the Thornthwaite method (79). The volume of wastewater applied minus the sum of runoff and evapotranspiration was considered percolation.

Table 12: Summary of Performance of Raw Sewage Plots During Phase I (January 1979 through May 1980)

Parameter	Raw Sewage			Raw Plot Effluent			
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)
BOD	165	62-270	31	22	3-50	29	87
TOC	93	44-204	19	36	21-54	36	61
Suspended Solids	140	40-464	33	24.5	2-122	46	82
Total Phosphorus	8.23	1.0-17.7	20	4.1	0.5-8.0	30	50
TKN - N	29.2	12.6-117	19	9.7	2.4-43	32	67
NH - N	18.0	3.5-136	31	2.8	0.04-13	45	84

Table 13: MEASURED APPLICATION RATES AND RUNOFF RATES ON OVERLAND FLOW PLOTS[1]

Plot	Application Rate (gpd)		Runoff (gpd)	Hydraulic Recovery (%)
	Design	Measured		
L1	38,400	10,000	7,225	72.3
L2	28,800	9,820	7,070	72.0
L3	19,200	6,090	4,490	73.7
L4	14,400	7,310	5,640	77.2
R2	32,400	20,680	16,500	79.8

[1] Measured on 5 June 1980

TABLE 14: LOADING AND RUNOFF FOR PLOT R2-PHASE 2

Date	Wastewater Applied (gpd)	Effluent Flow (gpd)	Percent Runoff	Application Rate (in/day)
7-8-80	5,142.9	4576.8	89.0	0.51
7-9	44,228.9	25,191.2	57.0	4.39
7-11	15,428.7	14,959.9	97.0	1.53
7-14	16,972.6	5,702.2	33.6	1.69
7-15	19,029.8	19,703.2	100.0	1.89
7-16	7,714.8	5,808.7	75.0	0.77
7-22*	18,515.5	11,978.0	64.7	1.84
7-23	18,515.5	11,978.1	64.7	1.84
7-24	16,972.6	15,488.6	91.3	3.52
7-25	19,029.8	17,512.8	92.0	1.89
7-29	20,058.5	13,252.8	66.1	3.88
7-30	23,658.7	23,104.0	97.7	2.35
7-31**	17,486.9	16,001.6	91.5	1.71
8-1	17,486.9	17,486.9	100.0	1.74
Ave.	18,588.7	14,481.8	77.9	2.11

*Flows for 7-22 and 7-23 were recorded together.
**Flows for 7-31 and 8-1 were recorded together.
To convert gpd to m^3/day multiply by 3.785×10^{-3}.
To convert in/day to cm/day multiply by 2.54.

Table 15 shows the performance of Plot R-2 in treating raw sewage during this summer period. The mean BOD_5 of the effluent was 14 mg/l, and the mean suspended solids concentration of the effluent was 21 mg/l. Removal efficiencies based on concentration were 88.9 percent and 90 percent respectively. When converted to mass removal efficiency by considering the runoff to average 77.9 percent of the applied wastewater, the results are 91.3 percent removal of BOD_5 and 92.2 percent removal of suspended solids. The reader should be reminded that this level of treatment was achieved during a period when approximately two inches of comminuted raw sewage was applied daily! Significant removals of nitrogen and phosphorus compounds were also achieved as can be seen in Table 15.

After this period of operation was completed at the end of August 1980, the raw sewage system was shut down to allow more careful attention to the operation of the system treating lagoon effluent. The raw sewage system has not been operated since that time.

TABLE 15: Performance of Raw Sewage Plots During Phase II--Study Period II
(May 1980 through August 1980)

Parameter	Raw Sewage			Average Raw Sewage Plot Effluent				
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)	Mass Removal (%)
Biochemical Oxygen Demand	126	73-187	6	14	5-26	7	88.9	91.3
Soluble BOD	39	23-46	6	4	3-6	7	89.7	92.0
Particulate BOD	87	50-143	6	10	2-20	7	88.5	91.1
Suspended Solids	210	118-376	7	21	11-28	7	90.0	92.2
Volatile Suspended Solids	180	101-313	7	18	9-26	7	90.0	92.2
Total Organic Carbon	101	77-148	7	40	26-54	8	60.4	69.2
Soluble Organic Carbon	39	34-48	7	34	20-46	8	12.8	32.1
Particulate Organic Carbon	62	43-108	7	6	1-11	8	90.3	92.5
Total Phosphorus (as P)	7.2	2.9-12.1	6	3.7	0.1-4.9	6	48.6	60.0
Ortho Phosphate (as P)	6.6	2.3-10.4	6	3.2	0.1-4.3	6	51.5	62.2
Total Nitrogen (as N)	31.9	28.5-33.3	6	10.2	2.66-19.5	8	68.0	75.1
Total Kjeldahl Nitrogen (as N)	30.3	22.1-36.0	7	8.11	1.20-19.3	8	73.2	79.2
Ammonia Nitrogen (as N)	16.5	12.6-19.5	7	4.06	<0.14-11.8	8	75.4	80.8
Nitrate Nitrogen (as N)	0.21	0.01-0.74	6	1.97	0.16-5.30	8	-838.1	-630.8
Nitrite Nitrogen (as N)	0.04	<0.01-0.20	7	<0.08	0.02-0.14	8	<-100.0	<-55.8

TREATMENT OF LAGOON EFFLUENT

Phase I

There were interruptions of lagoon effluent treatment during Phase I due to solenoid valve failures and severe weather. The lagoon pump station could not supply wastewater at a rate sufficient to reach the design operating schedule and rate. Otherwise, the system worked well. Lagoon effluent was successfully polished by treatment on overland flow plots.

The initial efforts at monitoring the lagoon plots were directed at measuring the effects of the different application rates and periods shown in Table 1. It rapidly became apparent that variations between different samples from the same plot were as great as the differences between samples from different plots receiving different loading rates. It appeared that the hydraulic and organic loadings to all plots were so low that the effluent concentrations were not controlled by loading rate. There seemed to be additional treatment capacity remaining even on the plots receiving the greatest amount of lagoon effluent. Therefore, the idea of statistially evaluating the effects of the planned application rates and schedules was not continued.

Table 16 contains the data on lagoon plot performance collected during the startup period. From Table 16 it can be seen that the lagoon plots removed 31 percent of the BOD_5 applied and produced a treated effluent with a mean BOD_5 of 20 mg/l. Suspended solids in lagoon plot effluent averaged 45 mg/l with wide variations in concentration. These results were obtained during the startup period in a time of intermittent operation and poor grass cover.

Table 17 contains data on the range and mean concentrations of measured parameters from July 1979 - November 1979. The cover crop had become well established by July and operational problems other than solenoid value failure had been ironed out. From the data contained in Table 17 it can be seen that the mean BOD_5 of lagoon plot effluent was 19 mg/l for a removal of 34.5 percent based on lagoon effluent concentration. Suspended solids removal improved with a mean value of 23 mg/l, an average removal of 49 percent. However, it was not unusual for lagoon plot effluent to exceed 30 mg/l suspended solids during this period due to algae present in the plot effluent.

During the cold weather monitoring period from February 1980 through May 1980, the same operational schedule continued for the lagoon effluent system. BOD removal continued to be satisfactory, but the suspended solids concentration usually exceeded 30 mg/l during this period. This increased suspended solids concentration was partly due to a higher concentration of

TABLE 16: Performance of the Lagoon Plots During Phase I--Startup Period (January 1979 through May 1979)

Parameter	Lagoon Effluent			Average Lagoon Plot Effluent			
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)
Biochemical Oxygen Demand	29	16-80	16	20	9-30	12	31.0
Soluble BOD	8	4-12	11	8	5-11	30	0.0
Particulate BOD	21	11-70	10	12	-	0	42.9
Suspended Solids	56	36-120	17	45	8-152	41	19.6
Volatile Suspended Solids	58	38-120	14	-	-	0	-
Soluble Organic Carbon	22	14-46	14	20	7-29	42	9.1
Total Phosphorus (as P)	3.2	2.8-3.9	12	2.0	0.6-3.7	42	37.5
Ortho Phosphate (as P)	2.4	1.1-3.4	12	1.5	0.3-3.2	38	37.5
Total Nitrogen (as N)	-	-	0	0.89	0.21-2.91	15	-
Total Kjeldahl Nitrogen (as N)	1.93	0.12-3.78	5	0.66	0.06-2.66	15	65.8
Ammonia Nitrogen (as N)	0.60	0.02-3.60	16	0.03	0.01-0.32	38	95.0
Nitrate Nitrogen (as N)	0.48	-	1	0.26	0.14-0.50	38	45.8

TABLE 17: Performance of the Lagoon Plots During Phase I--Study Period I (July 1979 through October 1979)

Parameter	Lagoon Effluent			Average Lagoon Plot Effluent			
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)
Biochemical Oxygen Demand	29	18-39	9	19	15-27	3	34.5
Soluble BOD	3	2-4	4	3	3-4	3	0.0
Particulate BOD	26	16-34	4	16	12-23	3	38.5
Suspended Solids	45	26-72	7	23	14-38	5	48.9
Volatile Suspended Solids	43	26-68	7	20	12-34	5	53.5
Total Organic Carbon	52	41-64	7	43	39-49	6	17.3
Soluble Organic Carbon	29	24-35	8	31	28-33	6	-6.9
Particulate Organic Carbon	23	15-37	7	12	7-17	6	47.8
Total Phosphorus (as P)	2.9	2.1-3.5	8	2.4	1.6-3.1	6	17.2
Ortho Phosphate (as P)	2.3	1.9-2.5	8	1.7	1.3-2.1	6	26.1
Total Nitrogen (as N)	-	-	0	5.03	3.41-7.81	4	-
Total Kjeldahl Nitrogen (as N)	8.76	2.36-15.6	9	5.14	3.08-7.63	6	41.3
Ammonia Nitrogen (as N)	0.56	0.02-1.54	9	0.12	0.02-0.43	6	78.6
Nitrate Nitrogen (as N)	-	-	0	0.51	0.22-0.87	4	-
Nitrite Nitrogen (as N)	0.09	0.02-0.21	8	0.09	0.03-0.13	6	0.0

suspended solids in the wastewater applied to the plots. See Table 18 for a summary of the results during this period.

Operation of the lagoon plots remained reasonably constant over all of Phase I. No deliberate changes in application rate or schedule were implemented. Thus, it seems reasonable to consider the data for the lagoon plots over the entire period of Phase I. Table 19 contains the weighted means for Phase I. These results indicate that applications of lagoon effluent to overland flow plots results in considerable improvement of the final effluent. Mean removals of 38 percent of BOD_5, 29 percent of suspended solids and 35 percent of the total phosphorus in the lagoon effluent, on the basis of concentration, resulted from the land treatment. Lack of reliable nitrate data on lagoon effluent prevents computation of total nitrogen, but 67 percent of both total Kjeldahl nitrogen and ammonia nitrogen were removed. The mean concentration of 40 mg/l suspended solids is affected by several measurements made during start-up when soil particles in the effluent led to very high values.

Phase II

The intended application rates for Phase II are shown in Table 3 on page 14 for the lagoon plots L-1 through L-4. Table 20 contains data on measured hydraulic loading rates and runoff for plots L-1, L-2, and L-4. It should be noted that the daily areal hydraulic loading rate was quite high during this period.

Table 21 contains a summary of the performance of lagoon plots L-1 through L-4 for this period of heavy hydraulic loading. The concentration of BOD_5 in the effluent remained low with a mean value of 13 mg/l. However, the suspended solids concentration in the effluent from the lagoon plots increased during this period. The mean concentration was 62 mg/l. It seemed that the unicellular algae produced in the lagoon moved with the applied lagoon effluent during the rapid application of water to the plots. Lagoon plot effluent was noticeably green. Filtration of samples of this green effluent in the laboratory removed the green color. The green material removed was essentially all algae cells when examined under a microscope.

Thirty-eight percent of the total phosphorus applied was removed from the wastewater along with 60 percent of the total nitrogen applied on a concentration basis. When mass removals were computed these values corresponded to 55 percent of the phosphorus applied and 63 percent of the nitrogen applied.

It would appear that this hydraulic application rate stressed the system with respect to suspended solids removal. The algae cells appear to have about the same specific gravity as water, and the cells tend to move through the grass on the plot and exit with the runoff.

TABLE 18: Performance of the Lagoon Plots During Phase I--Cold Weather Monitoring Period I (February 1980 through May 1980)

Parameter	Lagoon Effluent			Average Lagoon Plot Effluent				
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)	Mass Removal (%)
Biochemical Oxygen Demand	28	17-41	4	15	10-24	11	46.4	70.5
Soluble BOD	8	5-11	4	4	3-6	12	50.0	72.5
Particulate BOD	20	9-32	4	11	6-20	11	45.0	69.8
Suspended Solids	75	55-90	6	31	22-39	12	58.7	77.3
Volatile Suspended Solids	61	52-80	6	23	17-30	12	62.3	79.3
Total Organic Carbon	52	37-61	6	38	20-42	9	26.9	59.8
Soluble Organic Carbon	28	18-33	6	29	19-34	9	-3.6	43.0
Particulate Organic Carbon	24	19-34	6	9	1-13	9	62.5	79.4
Total Nitrogen (as N)	3.73	-	1	2.79	1.33-4.37	8	25.2	58.9
Total Kjeldahl Nitrogen (as N)	4.88	3.45-6.30	2	2.29	1.05-3.60	8	53.1	74.2
Ammonia Nitrogen (as N)	1.91	1.00-3.05	3	<0.14	-	8	>92.7	>96.0
Nitrate Nitrogen (as N)	<0.14	-	1	<0.30	<0.14-0.56	8	<-114.3	<-17.9
Nitrite Nitrogen (as N)	<0.24	<0.14-0.43	4	<0.19	<0.14-0.40	8	>20.8	>56.5

Table 19: Summary of Performance of Lagoon Plots during Phase I
(January 1979 through May 1980)

Parameter	Lagoon Effluent			Lagoon Plot Effluent			
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)
BOD	29	16-80	29	18	9-30	26	38
TOC	52	37-64	13	40	20-49	15	23
Suspended Solids	57	26-120	30	40	8-152	58	29
Total Phosphorus (as P)	3.1	2.1-3.9	20	2.0	0.6-3.7	48	35
Total Kjeldahl Nitrogen (as N)	6.1	0.12-15.6	16	2.0	0.06-7.6	29	67
Ammonia nitrogen (as N)	0.48	0.02-3.6	33	0.16	0.01-0.43	47	67

TABLE 20: LOADING AND RUNOFF FOR PLOTS L1, L2 AND L4 - PHASE II

Date	Wastewater Applied (gpd)	Effluent Flow (gpd)	Percent Runoff	Application Rate (in/day)
		Plot L1		
7-11	7,322.9	3,439.8	47.0	1.00
7-16	5,363.2	4,628.4	86.3	0.74
7-17	20,128.7	14,020.8	69.7	2.76
7-24	21,804.2	18,945.0	86.9	2.99
7-25	20,906.6	14,836.5	71.0	2.87
7-29	11,893.2	8,424.0	70.8	1.63
7-30	22,484.9	16,050.0	71.4	3.08
7-31	11,653.8	8,040.3	69.0	1.60
8-1	10,486.9	7,050.0	67.2	1.44
Ave. L1	14,671.6	10,603.87	72.3	2.01
		Plot L2		
7-11	6,986.3	5,850.2	69.4	0.84
7-15	25,993.0	16,683.0	64.2	3.12
7-16	21,662.1	13,905.4	64.2	2.60
7-17	9,185.4	6,267.4	68.2	1.10
7-22*	16,695.4	10,329.0	61.9	2.00
7-23	16,695.3	10,329.1	61.9	2.01
7-24	22,873.8	20,427.4	89.3	2.75
7-25	21,579.8	16,528.8	76.6	2.61
7-29	12,910.5	9,625.4	74.6	1.55
7-30	22,664.4	16,886.8	74.5	2.72
7-31	12,035.3	9,370.2	77.9	1.45
8-1	10,741.3	8,807.2	82.0	1.29
Ave. L2	16,643.0	12,015.8	72.0	2.00
		Plot L4		
7-11	5,925.4	2,706.9	45.7	0.69
7-17	8,759.1	5,697.4	65.0	1.02
7-22*	15,846.4	9,792.8	61.8	1.84
7-23	15,846.4	9,792.7	61.8	1.84
7-24	21,056.2	20,837.0	98.9	2.45
7-25	18,385.8	13,823.5	75.2	2.14
7-29	12,110.1	10,905.5	90.1	1.41
7-30	21,400.3	15,268.8	71.3	2.49
7-31	11,205.0	7,888.4	70.4	1.30
8-1	10,621.6	8,469.6	79.7	1.23
Ave. L4	14,107.3	10,887.6	77.1	1.64

*Flows for 7-22 and 7-23 were recorded together.
To convert gpd to m^3/day multiply by 3.785×10^{-3}.
To convert in/day to cm/day multiply by 2.54.

TABLE 21: Performance of the Lagoon Plots During Phase II--Study Period II (June 1980 through August 1980)

Parameter	Lagoon Effluent			Average Lagoon Plot Effluent				
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)	Mass Removal (%)
Biochemical Oxygen Demand	35	16-65	6	13	7-19	18	62.9	72.6
Soluble BOD	3	2-8	6	2	1-3	18	33.3	50.8
Particulate BOD	32	14-57	6	11	5-16	18	65.6	74.6
Suspended Solids	107	76-140	7	62	31-82	20	42.1	57.2
Volatile Suspended Solids	100	75-131	7	55	28-75	20	45.0	59.4
Total Organic Carbon	64	56-84	7	50	36-61	20	21.9	42.3
Soluble Organic Carbon	33	20-40	7	34	23-47	20	-3.0	24.0
Particulate Organic Carbon	31	21-47	7	16	6-27	20	48.4	61.9
Total Phosphorus (as P)	3.9	3.3-4.9	6	2.4	1.5-3.2	8	38.5	54.6
Ortho Phosphate (as P)	3.2	2.2-4.2	6	2.3	1.1-2.9	7	28.1	47.0
Total Nitrogen (as N)	14.4	9.72-17.3	6	7.21	3.19-13.5	20	49.9	63.1
Total Kjeldahl Nitrogen (as N)	13.2	8.20-17.1	7	6.68	3.80-13.5	20	49.4	62.7
Ammonia Nitrogen (as N)	<0.40	<0.14-1.52	7	<0.16	0.06-0.49	20	>60.0	>70.5
Nitrate Nitrogen (as N)	0.34	0.06-0.68	6	0.50	0.02-1.31	20	-47.1	<-8.5
Nitrite Nitrogen (as N)	<0.04	0.01-<0.14	7	<0.04	<0.01-<0.14	20	>0.0	>26.2

Phase III

In September 1980 the application rate was reduced for lagoon plots 1, 2, 3, and 4, and the remaining six lagoon plots were put back into service. Wastewater was applied for fourteen hours per day, five days per week. This should have resulted in a mean hydraulic loading rate of about 3.6 cm (1.4 inch) per day. However, it was very difficult to adjust the flow uniformly, and it was apparent that certain plots were receiving more wastewater than others. The uneven application did not seem to affect treatment. All loading rates were apparently low enough to leave the plots with reserve capacity for treating additional wastewater.

Table 22 contains the means of measurements made during the cold weather period from September 1980 through April 1981. Limited data were collected, but the lagoon plots seemed to remove over 50 percent of the BOD_5 and suspended solids in the lagoon effluent and about 29 percent of the total organic carbon.

Results from May 1981 through September 1981 have been compiled in Table 23. Inspection of Table 23 indicates that during this warm weather period the plots did an excellent job of polishing the lagoon treated wastewater. The effluent BOD_5 and suspended solids concentration averaged 10 mg/l and 17 mg/l, respectively. Effective removals of total phosphorus and ammonia nitrogen were also recorded. An occasional sample contained more than 30 mg/l suspended solids in samples collected from individual plot weirs. Treatment continued in the collection channels so that final effluent suspended solids concentration seldom exceeded 30 mg/l.

BACTERIOLOGICAL STUDIES

Waterborne Analyses

Samples were taken approximately once a month between the months of February and December, 1980. Meteorological conditions were recorded for three days before the sample day, so that possible effects of the weather on the system could be evaluated. Tabulated weather data for waterborne analyses are presented in Table 24. Temperature and precipitation are reported as these factors seemed most pertinent to the waterborne analyses. Most samples were collected after a dry period, therefore all plot loading was from wastewater during these dates.

The geometric mean for all sample dilutions was computed for each location on each sample date. Overall results are tabulated in Tables 25, 26, and 27, and the geometric mean of all results are listed in Table 28.

TABLE 22: Performance of the Lagoon Plots During Phase III--Cold Weather Monitoring Period II (September 1980 through May 1981)

Parameter	Lagoon Effluent			Average Lagoon Plot Effluent			
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)
Biochemical Oxygen Demand	29	16-40	4	14	13-16	4	51.7
Suspended Solids	84	33-143	6	36	20-74	7	57.1
Volatile Suspended Solids	79	32-130	2	33	19-75	3	58.2
Total Organic Carbon	63	50-76	6	45	42-49	6	28.6

TABLE 23: Performance of the Lagoon Plots During Phase III--Study Period III (May 1981 through September 1981)

Parameter	Lagoon Effluent			Average Lagoon Plot Effluent				
	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Mean Conc. (mg/l)	Range (mg/l)	# of Samples	Conc. Removal (%)	Mass Removal (%)
Biochemical Oxygen Demand	42	22-57	6	10	2-24	15	76.2	92.1
Soluble BOD	5	-	1	5	-	2	0.0	67.0
Particulate BOD	37	-	1	5	-	2	86.5	95.5
Suspended Solids	107	32-143	7	17	5-43	14	84.1	94.8
Volatile Suspended Solids	93	-	1	16	-	2	82.8	94.3
Total Organic Carbon	69	56-80	7	49	38-61	15	29.0	76.6
Soluble Organic Carbon	39	-	1	43	-	2	-10.3	63.6
Particulate Organic Carbon	30	-	1	6	-	2	80.0	93.4
Total Phosphorus (as P)	4.6	2.5-5.5	6	3.3	2.6-4.2	10	28.3	76.3
Ammonia Nitrogen (as N)	0.85	0.04-1.65	2	0.08	0.05-0.10	2	90.6	96.9

Table 24. Weather Conditions for Waterborne Analyses

DATE	TEMPERATURE MAX	MIN	MEAN	PRECIP	DATE	TEMPERATURE MAX	MIN	MEAN	PRECIP
Feb 19	54	28	41	0	Jun 23	86	63	74	0
20	50	39	44	0	24	80	65	72	0.25
21	65	39	52	0.02	25	72	61	66	1.50
Mar 25	68	40	54	0.62	Jul 7	94	68	81	0
26	--	44	--	0	8	96	64	80	0
27	66	43	54	0	9	100	70	85	0
Apr 22	83	55	69	0	21	94	72	83	0
23	91	56	74	0	22	92	71	82	0
24	88	58	73	0	23+	90	71	80	T
May 20	74	59	66	0.39	Aug 19	95	69	82	0.01
21	81	53	67	1.87	20	96	66	81	0.20
22	78	60	69	0	21	97	69	83	0
27	82	57	70	0	Sep 15	96	66	81	0
28	86	59	72	0	16	94	67	80	0
29	86	63	74	0	17	84	67	76	0
Jun 18	80	61	70	T	Dec 28	55	--	--	0.01
19	79	63	71	0.55	29	67	40	54	0.31
20+	88	62	75	0	30	46	42	44	0.01

+ designates profile sample dates.

Table 25. Total Coliform Results (#/100 ml x 10^{-4})

DATE	RAW INF	LAGOON EFF	TOTAL SYSTEM EFF	STREAM A	STREAM B	STREAM C	STREAM D	STREAM E
2/21	190	0.40	2.90	0.49	<0.001	0.07	<0.001	-NS-
3/27	3066	-NS-	38.3	0.04	0.001	0.07	0.04	-NS-
4/24	1724	5.01	24.8	0.04	0.27	0.05	0.22	-NS-
5/22	761	16.1	4.35	0.04	<0.001	0.23	0.01	-NS-
5/29	2057	4.38	8.40	0.06	0.12	0.13	0.12	-NS-
6/25	797	14.8	26.4	0.09	<0.001	0.98	0.54	-NS-
7/09	3944	2.34	13.9	0.09	<0.001	0.32	<0.001	0.15
8/21	8763	12.4	99.6	0.46	<0.001	0.45	0.05	0.53
9/17	-NS-	12.2	10.9	0.30	0.20	TNTC	TNTC	0.92
12/30	65.4	10.8	0.90	0.09	TNTC	0.74	2.01	0.72

NS = not sampled
TNTC = too numerous to count

Table 26. Fecal Coliform Results (#/100 ml x 10^{-4})

DATE	RAW INF	LAGOON EFF	TOTAL SYSTEM EFF	STREAM A	STREAM B	STREAM C	STREAM D	STREAM E
2/21	52.0	0.01	0.35	0.18	<0.001	0.02	<0.001	-NS-
3/27	193.4	-NS-	16.3	0.002	<0.001	0.005	0.001	-NS-
4/24	129.5	0.10	14.9	0.01	0.05	0.01	01.0	-NS-
5/22	54.8	0.53	0.25	0.01	<0.001	0.02	<0.001	-NS-
5/29	231.9	0.53	0.12	0.13	0.02	0.03	-NS-	
6/25	121.2	0.91	3.41	0.007	<0.001	0.20	0.06	-NS-
7/09	823.5	2.34	13.9	0.10	<0.001	0.32	<0.001	0.15
8/21	834.4	22.6	25.1	0.10	<0.001	0.13	0.001	0.17
9/17	-NS-	1.51	1.05	0.05	0.03	TNTC	TNTC	0.21
12/30	31.6	3.55	4.30	0.04	1.94	0.19	1.01	0.32

Table 27. Fecal Streptococci Results (#/100 ml x 10^{-4})

DATE	RAW INF	LAGOON EFF	TOTAL SYSTEM EFF	STREAM A	STREAM B	STREAM C	STREAM D	STREAM E
2/21	6.30	0.20	0.67	0.80	<0.001	0.009	<0.001	-NS-
3/27	44.9	-NS-	1.25	0.001	0.01	0.008	0.003	-NS-
4/24	22.1	<0.10	0.31	0.01	0.007	0.009	0.10	-NS-
5/22	<10.0	0.05	0.10	0.01	<0.001	0.02	<0.001	-NS-
5/29	100.5	0.30	0.75	0.20	0.39	0.21	0.26	-NS-
6/25	189.7	1.24	6.56	0.13	0.004	0.59	0.03	-NS-
7/09	89.4	0.63	2.58	0.10	0.003	0.15	0.001	0.01
8/21	280.6	3.52	47.9	0.16	TNTC	0.20	TNTC	0.08
9/17	-NS-	0.42	8.73	0.27	0.01	TNTC	TNTC	0.39
12/30	50.0	1.28	1.95	0.04	0.85	0.37	0.61	0.18

NS = not sampled
TNTC = too numerous to count

Table 28. Overall Geometric Means (#/100 ml x 10^{-4})

LOCATION	TOT COLIFORMS	FEC COLIFORMS	FEC STREPTOCOCCI
Raw Influent	1122.6	152.10	48.536
Lagoon Effluent	5.8477	0.9646	0.4183
Tot. Sys. Effluent	11.363	2.5848	1.7489
Stream A	0.1072	0.0181	0.0465
Stream B	<0.0057	<0.0072	<0.0144
Stream C	0.2076	0.0738	0.0648
Stream D	<0.0431	<0.0083	<0.0136
Stream E	0.4770	0.2020	0.0920

Since there was approximately twice as much wastewater contributed by the lagoon as there was from the raw sewage, the lagoon effluent was given twice as much weight as the raw sewage when calculating percent reductions over the treatment system. The percent reductions for each bacterial type is given in Table 29. On March 27, no lagoon effluent was being treated, and the percent reduction was interpreted as accurately assessing the efficiency of the raw sewage treatment system. On September 17, no raw sewage was being treated, and the efficiency of treating only lagoon effluent could be assessed.

Table 29. Percent Bacterial Reductions in Overland Flow System

DATE	TOT COLIFORMS	FEC COLIFORMS	FEC STREPTOCOCCI
Feb 21	98.5	99.3	90.0
Mar 27	98.8	91.6	97.2
Apr 24	98.6	88.5	98.6
May 22	99.5	99.6	99.0
May 29	99.6	99.9	99.3
Jun 25	96.8	97.2	96.6
Jul 9	99.6	99.6	97.2
Aug 21	98.9	97.1	83.3
Sept 17	10.6	30.5	0
Dec 30	89.7	88.9	96.3

A profile of plot R2 was sampled on two dates during the summer. Samples were analyzed for fecal coliforms and fecal streptococci. Weather conditions were noted as in the routine analyses and are included in Table 24. Results of the profile samples are shown in Table 30, and graphed in Figures 4 and 5.

Table 30. Profile Studies of Bacterial Removal on Plot R2 (#/100 ml x 10^4)

SAMPLE LOCATION	FECAL COLIFORMS		FECAL STREPTOCOCCI	
	June 20	July 30	June 20	July 23
Raw Influent	137.1	380.7	148.1	518.0
25 Feet Down	270.5	430.3	155.1	178.4
50 Feet Down	166.5	249.0	153.8	639.4
75 Feet Down	11.35	181.3	89.75	318.2
100 Feet Down	9.587	32.53	78.22	311.6
135 Feet Down	5.123	112.4	2.579	278.3
Plot Effluent	3.697	79.49	5.754	102.3
Percent Reduction	97.3	79.1	96.1	80.2

Bacterial Aerosol Results

Meteorological conditions were noted at the time of sampling, with particular attention paid to temperature, wind conditions, sky conditions, and evaporation rate. Evaporation rate was obtained from the Clemson University Agricultural Weather office. It should be noted that evaporation is a function of temperature, relative humidity, wind conditions, and other conditions. Meteorological conditions at the time of sampling are presented in Table 31.

Table 31. Weather Conditions During Airborne Sampling

DATE	TEMPERATURE	WIND		EVAPORATION	SKY
		Dir	Speed		
Jul 4	95	SW	4	0.21	clear
11	100	Var	2	0.23	clear
18	90	SW	5	0.36	clear
25	90	NE	10	0.21	P. cdy
17	80	E	5	0.15	cloudy
Oct 14	62	E	2	0.12	cloudy
Dec 30	38	NE	7	0.10	cloudy

[1]Evaporation interpreted as inches vaporized from wet pan in 24 hour period.

Aerosol samples were successfully collected on seven dates in 1980. Total aerobic heterotrophic bacteria results are contained in Table 32. Results for total coliforms are shown in Table 33. Geometric means for all

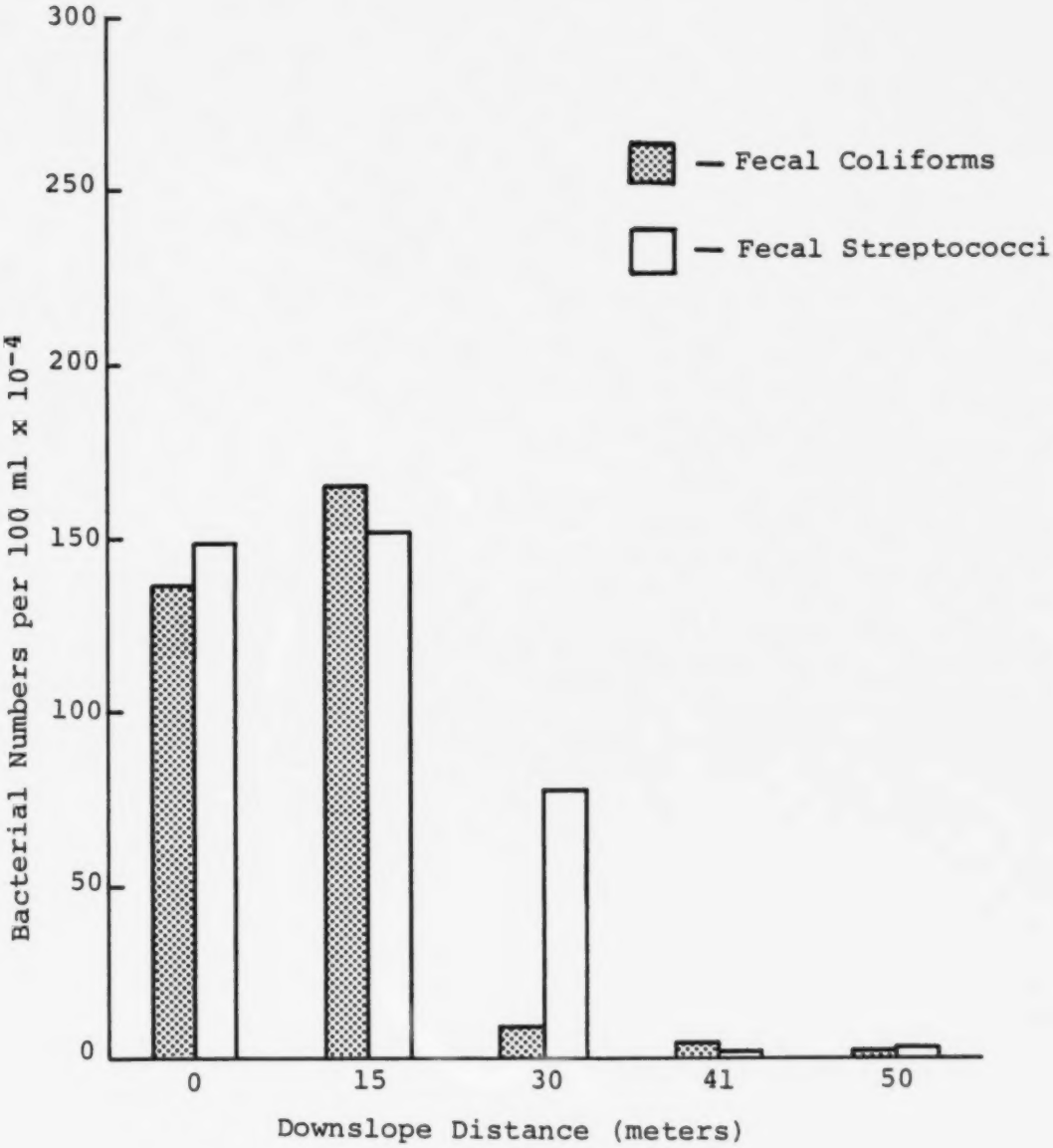

Figure 4. Bacteria Profile on Plot R2
June 20, 1980

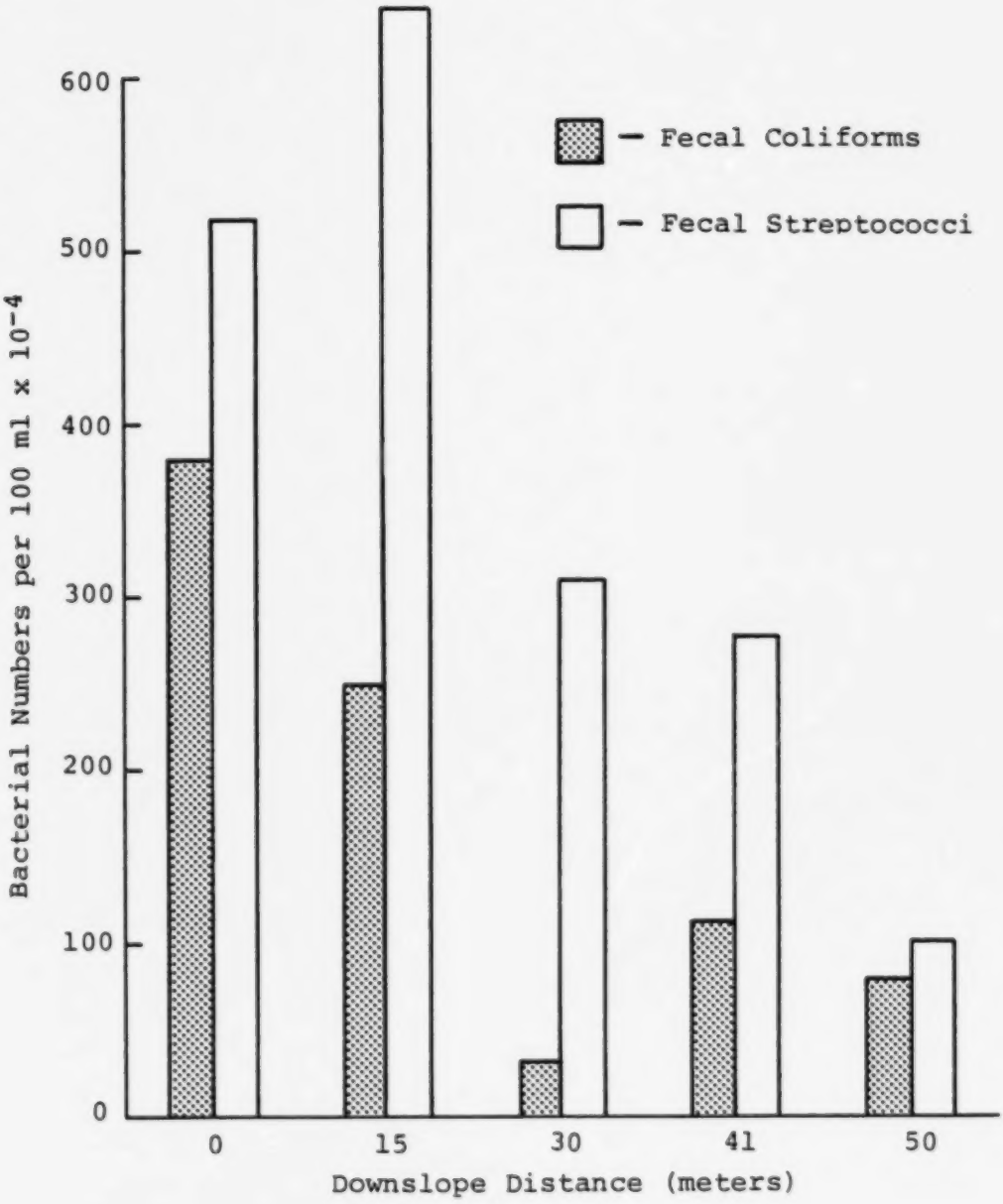

Figure 5. Bacteria Profile on Plot R2
July 23, 1980

samples were calculated and are plotted in Figures 6 and 7. Results for the bacterial aerosol studies were variable. Samples collected at 1.5 meters downwind from the spray nozzles consistently contained more bacteria, both coliforms and total aerobic heterotrophic bacteria, than the upwind samples. Droplets may have been collected this near the spray pattern. The samples collected at the greater distances sometimes contained fewer bacteria than the upwind samples and sometimes contained greater numbers of bacteria.

Table 32. Total Bacteria in Aerosols (#/m^3)

DATE	UPWIND	1.5 M DOWN	9.1 M DOWN	18.3 M DOWN	30.5 M DOWN
Jul 4	858.1	-NS-	427.3	858.1	610.9
11	211.9	-NS-	840.4	1398.3	63.6
18	939.3	-NS-	1186.4	459.0	-NS-
25	1998.9	-NS-	176.6	2994.4	2613.0
Sep 17	169.5	-NS-	409.6	>4000	>4000
Oct 14	233.1	282.5	162.4	466.1	-NS-
Dec 30	28.2	2259.9	113.0	35.3	-NS-
Geo Mn	325	799	344	548	466

Table 33. Total Coliform in Aerosols (#/m^3)

DATE	UPWIND	1.5 M DOWN	9.1 M DOWN	18.3 M DOWN	30.5 M DOWN
Jul 4	<1.8	-NS-	105.9	5.3	14.1
11	7.1	-NS-	<1.8	10.6	8.8
18	7.1	-NS-	<1.8	<1.8	-NS-
25	49.4	-NS-	1.8	1.8	17.7
Sep 17	<1.8	-NS-	10.6	3.5	5.3
Oct 14	<1.8	<1.8	3.5	<1.8	-NS-
Dec 30	<1.8	84.7	3.5	1.8	-NS-
Geo Mn	3.0	9.2	4.2	2.5	10.4

Note: NS = not sampled

GROUNDWATER STUDY RESULTS

The ten test wells were installed as located on Figure 8 where test wells are designated W1, W2, etc. Total depths and screen locations are shown in Table 34 along with average water table elevations.

An intensive study of groundwater conditions was conducted during the summer of 1981 when the overland flow system had been operating more than two years.

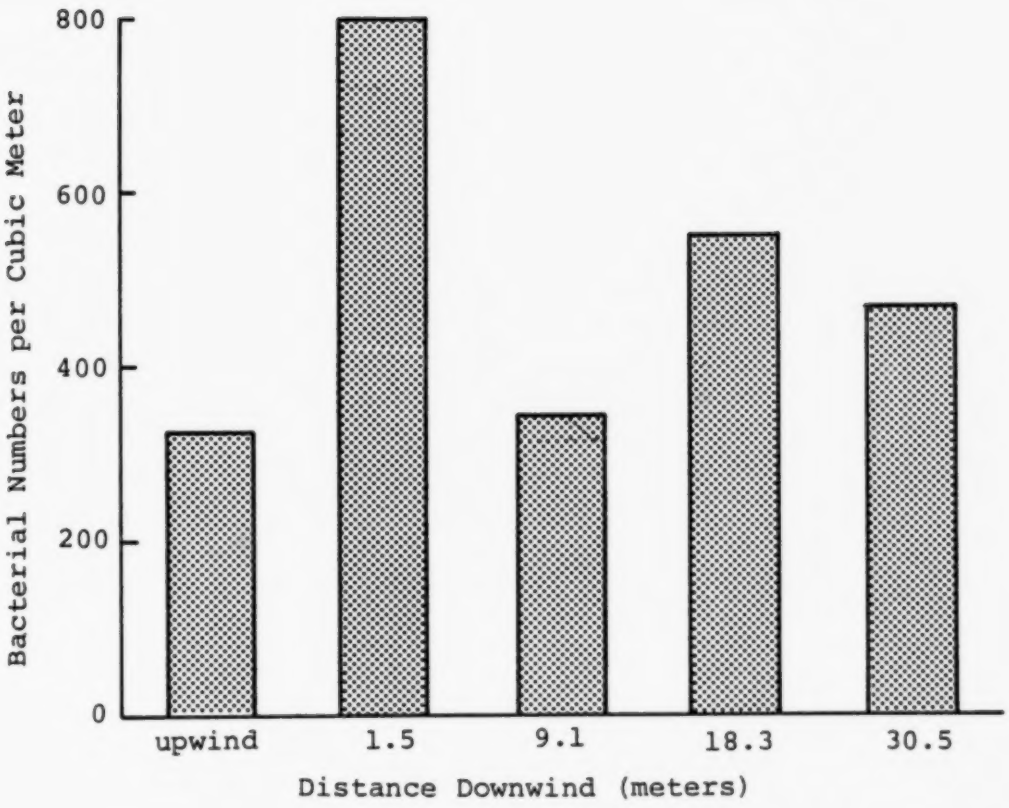

Figure 6. Geometric Means of Total Bacteria Aerosols

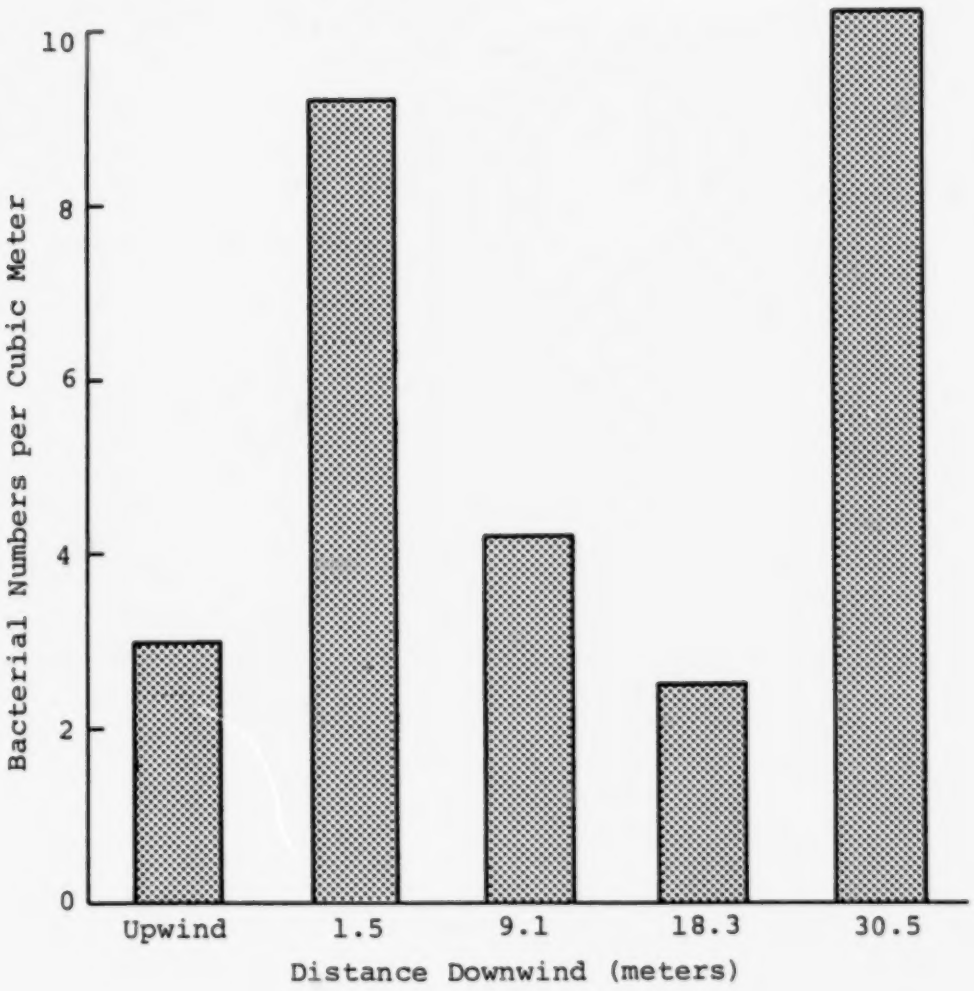

Figure 7. Geometric Means of Total Coliform Aerosols

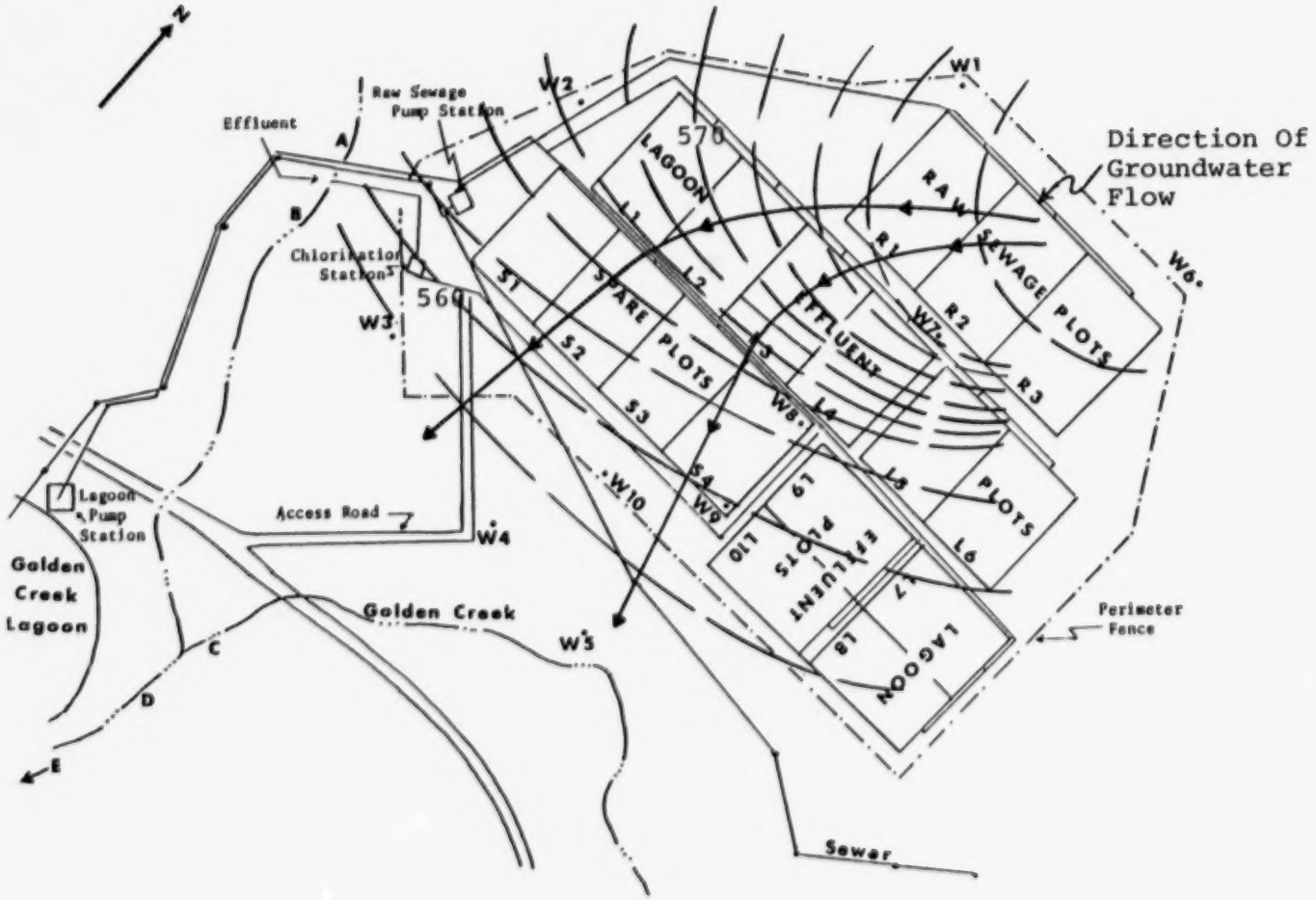

Figure 8. Water Table Contours, Easley Overland Flow Site

Table 34: MONITORING WELL INFORMATION

Well Number	Total Depth Ft.	Screen Location, Ft	Average Water Elevation, Ft.
1	30.0	25-30	977.66
2	19.0	14-19	967.06
3	15.0	10-15	957.44
4	15.0	10-15	965.43
5	9.0	4-9	957.98
6	40.0	29-34	980.31
7	25.0	20-25	976.95
8	30.0	22-27	961.47
9	30.0	20-25	959.97
10	25.0	16-21	958.48

TABLE 35: FECAL COLIFORM RESULTS

Sample Date	Sample Location				
	Well 3	Well 4	Well 6	Well 8	Golden Creek
6/4/81	0	-	0	0	>80
6/11/81	0	0	0	0	>80
6/17/81	0	0	0	0	>80
6/25/81	2	0	0	0	>80
7/1/81	0	0	0	0	>80
7/9/81	0	0	0	0	>80
7/16/81	0	0	0	0	>80

Note: All results are expressed as fecal coliforms/100 ml.

Measurements of depth to the groundwater surface along with the elevation of the top of the well casing (Table 34) allowed preparation of the map of water table contours shown in Figure 8. Constructing perpendicular lines to the contours allowed estimation of the direction of groundwater flow. From Figure 8 it appears that wells 3, 4, 8, 9, and 10 were valid locations for monitoring the groundwater downstream of the raw sewage plots and plots L1 through L4 which have been the most heavily used of the lagoon plots.

Fecal coliform results from groundwater samples are shown in Table 35. Only the sample from well 3 on June 25, 1981 showed any evidence of fecal coliform contamination. This may have resulted from contamination which occurred while measuring the water surface elevation.

Results of nitrate determinations are shown in Table 36. Comparison of results from the other wells to those from reference wells 1 and 6 indicates a possible increase in nitrate downstream of the reference wells. However, any increase seems insignificant when compared to the 45 mg/l nitrate (or 10 mg/l nitrate nitrogen) concentration allowable in drinking water.

Interestingly, samples from two private wells within a half mile west of the project showed nitrate concentration of 11.8 and 7.0 mg/l as nitrate. Also, Golden Creek upstream of the treatment system outfall usually contained higher concentrations of nitrate than the groundwater samples.

Samples of water from the monitoring wells were also tested for chloride content with the results summarized in Table 37. In most instances the chloride concentration in the reference wells was slightly higher than that found in the downgradient monitoring wells. The samples from Golden Creek were also higher in chloride concentration than were the samples from the monitoring wells.

It was expected that phosphorus compounds would be effectively bound by the clay minerals in the soil. However, total dissolved phosphorus measurements were made on samples from the monitoring wells in order to improve understanding of the groundwater and to provide a baseline for future monitoring. Table 38 contains a summary of those results.

These results led to the conclusion that over two years operation of the Easley overland flow project has not resulted in any damage to the quality of the underlying aquifer. Although some portion of the water applied to the plots seems to be lost by percolation to the groundwater, mechanisms such as filtration, microbiological reactions, adsorption, and dilution prevented damage to the bacteriological or chemical quality of the groundwater.

TABLE 36: SUMMARY OF NITRATE ANALYSES[a] OF GROUNDWATER SAMPLES

Sample Date	Sample Location											
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	TSE[b]	Stream[c]
6/4/81	0.99	<0.10	<0.10	0.53	0.38	0.64	0.47	0.62	0.62	0.35	-	-
6/11/81	1.25	0.13	0.22	1.08	0.30	0.63	0.75	1.15	1.20	0.76	0.15	1.22
6/17/81	0.09	0.05	0.21	0.47	0.18	0.43	0.58	1.40	1.12	0.61	0.31	1.39
6/25/81	1.48	0.45	0.37	1.58	0.72	0.72	0.98	1.35	1.43	1.02	1.83	0.73
7/1/81	1.58	0.33	0.32	1.17	-	0.66	0.79	1.10	1.10	1.12	-	1.20
7/9/81	1.28	0.43	0.32	1.43	-	0.77	0.92	1.20	1.30	0.73	-	1.43
7/16/81	1.06	0.13	0.20	0.98	-	0.58	0.68	0.88	1.55	0.66	-	1.30
average	1.16	0.23	0.24	1.03	0.40	0.63	0.73	1.10	1.19	0.75	.76	1.04

[a]All Results reported in mg/l as Nitrate
[b]TSE - Total System Effluent
[c]Stream - Golden Creek just below well #5.

Table 37: Summary of Chloride Analysis of Groundwater Samples

Sample Location	Chloride Concentration, mg/l as Cl (average)	(range)
Well 1	3.27	1.30-6.40
Well 2	2.30	1.65-2.85
Well 3	3.54	2.00-7.20
Well 4	4.20	3.15-5.80
Well 5	Not Sampled	---------
Well 6	4.04	3.60-5.80
Well 7	5.47	4.40-6.90
Well 8	3.45	2.70-4.40
Well 9	4.50	2.70-5.90
Well 10	5.17	3.60-6.40
Golden Creek	10.40	7.10-13.10
Lagoon Effluent	48.00	44.00-52.00
Total System Effluent	44.00	43.00-45.00

Table 38: Total Dissolved Phosphorous Results for Groundwater Samples

Sample Location	Phosphorus Concentration, mg/l p (average)	(range)
Well 1	0.007	0.000-0.021
Well 2	0.030	0.015-0.039
Well 3	0.002	0.000-0.006
Well 4	0.000	0.000-0.000
Well 5	Not Sampled	----------
Well 6	0.002	0.000-0.006
Well 7	0.004	0.000-0.009
Well 8	0.001	0.000-0.002
Well 9	0.001	0.000-0.002
Well 10	0.001	0.000-0.003
Golden Creek	0.023	0.000-0.043
Lagoon Effluent	4.340	3.250-5.380
Total System Effluent	3.670	3.400-3.850

SECTION 6

DISCUSSION

TREATMENT OF RAW SEWAGE

Treatment of comminuted raw sewage resulted in a good quality effluent which appeared sparkling clear to the observer. Table 39 contains a summary of the results of raw sewage treatment from start-up until raw sewage treatment was discontinued in August, 1980. BOD_5 removal on a concentration basis was 87 percent. Removal of suspended solids averaged 85 percent. Removal of total phosphorous and total nitrogen averaged 50 percent and 62 percent, respectively. Mean concentrations in the treated effluent were 21 mg/l BOD_5, 24 mg/l suspended solids, 36 mg/l total organic carbon, 4.0 mg/l total phosphorous, and 12 mg/l total nitrogen. Of that total nitrogen content only three mg/l existed as ammonia.

These results indicate that overland flow does an effective and reliable job of treating comminuted raw sewage. This process should be seriously considered for relatively small towns where appropriate land is available at reasonable costs.

Effects of Flow Distance

Profile studies on raw sewage plots were made on 21 different dates. These data are included in the appendix tables. Figure 9 is a graph of the means of these results for BOD_5 plotted versus flow distance. It can be seen that rapid removal of BOD_5 occurs in the first 15 meters of plot length. Removal of BOD appears to be exponential and further flow distance would have resulted in a slightly greater removal.

Figure 10 contains a plot of the organic carbon profile means. Again, an exponential curve is the result. On certain dates irregularities resulted from the sudden movement of solid particles which affected BOD determinations, organic carbon measurements, and suspended solids data. However, the graphs shown in Figure 9 and 10 are representative of the profile data for BOD_5 and organic carbon.

Graphical presentation of the means of profile studies was chosen over profile plots for each set of data partially to save space and partially because of irregularities resulting from the problems of collecting representative samples down the slope. Plotting the means of all data sets

Table 39: Summary of Performance of Raw Sewage Plots from January 1979 through August 1980

Parameter	Raw Sewage			Raw Sewage Plot Effluent			
	Mean Conc. (mg/1)	Range (mg/1)	# of Samples	Mean Conc. (mg/1)	Range (mg/1)	# of Samples	Conc. Removal (%)
BOD	157	62-270	37	21	3-50	36	86.9
Suspended Solids	161	40-464	38	24	2-122	53	85.1
Total Organic Carbon	95	44-204	26	36	20-54	44	61.8
Total Phosphorus (as P)	8.0	1.0-1.7	26	4.0	0.1-8.0	36	50.0
Total Nitrogen (as N)	32	28-33	6	12	2.7-43.7	31	62.5
Ammonia Nitrogen (as N)	18	3.6-136	38	3.0	0.04-13	53	83.3

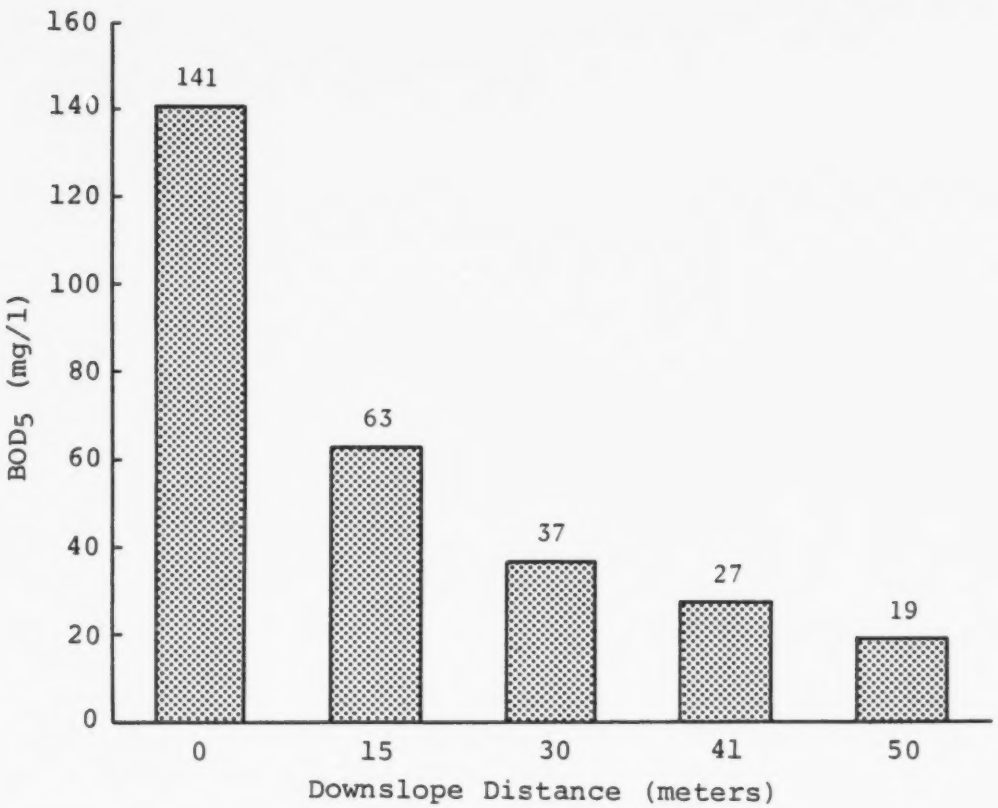

Figure 9. BOD_5 Profile - Raw Sewage Application

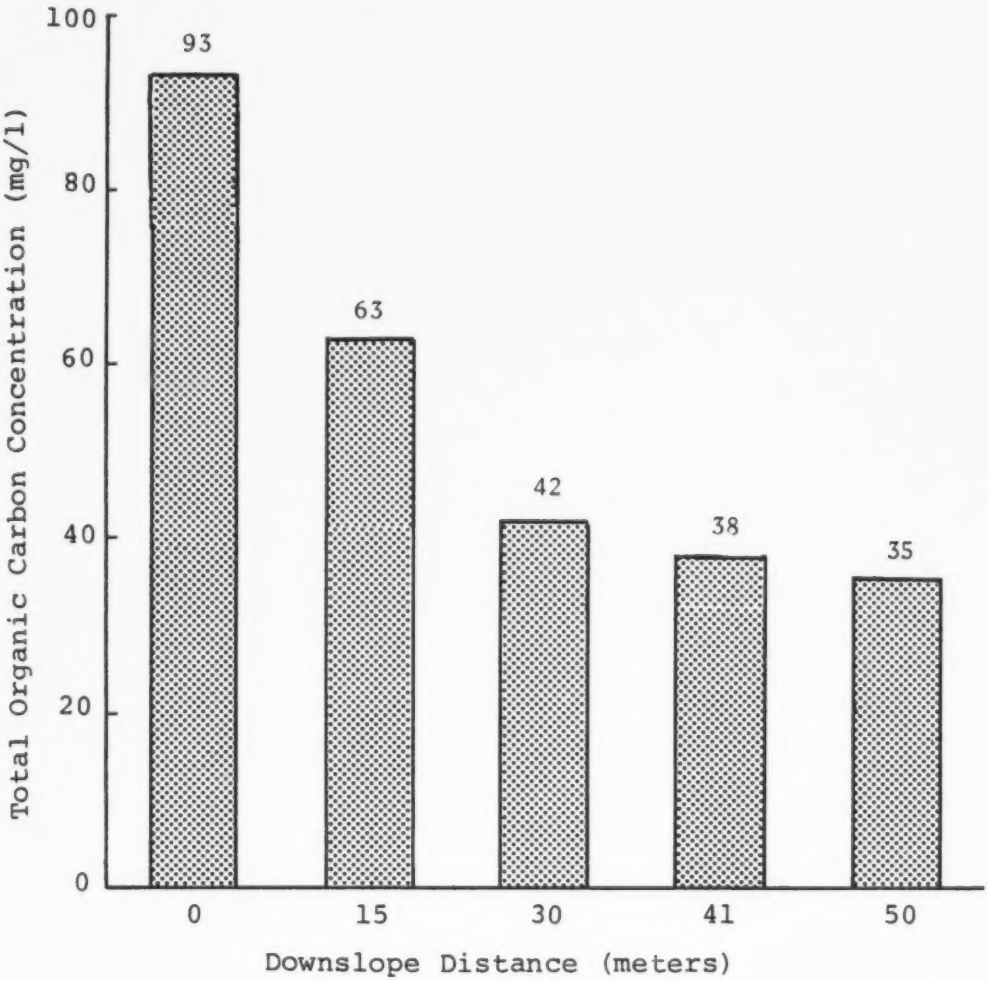

Figure 10. Total Organic Carbon Profile
Raw Sewage Application

smooths out irregularities due to irregular distribution of suspended solids over the plot, but may result in masking some other important aspects of the effects of flow distance.

Figure 11, a plot of suspended solids concentration versus distance of flow, again appears to present a curvilinear relationship. Greater plot lengths, or distance of flow, should result in lower suspended solids concentrations in the plot effluent. However, the suspended solids concentration appears to be approaching a threshold value which would probably remain reasonably constant even if plot lengths were considerably increased. This threshold value, or range of values, is probably similar to the suspended solids concentration of runoff from comparable plots receiving no wastewater, only rainfall. Such a threshold value or minimum concentration also probably applies to BOD, organic carbon, and nutrient concentrations as well.

Figure 12 is a plot of nitrogen compound means down the raw sewage plots. From Figure 12 it can be seen that organic nitrogen compounds and ammonia nitrogen are both effectively removed by overland flow. Not much nitrate or nitrite nitrogen is applied in the raw sewage, and much of the nitrate nitrogen produced on the plots appears to be lost by denitrification. The high degree of ammonia removal should assist in reducing oxygen demand of the overland flow facility effluent when it reaches the receiving stream.

Figure 13 is a profile plot of the means of the phosphorus determinations. Organic phosphorus compounds are more effectively removed on the plots, probably because the organic phosphorus compounds are associated with particles. However, most of the phosphorus applied is in the orthophosphate form, and this is the form which constitutes most of the phosphorus in the plot effluent. Additional plot length should result in lower phosphorus concentrations, based on these results.

In conclusion, the choice of 50 meters (165 feet) slope length for the raw sewage plots seems to have been a fortunate one. Significant removals of BOD_5, organic carbon, nitrogen, and phosphorus occur between the 41 meter and 50 meter locations on the plot. Greater slope length should result in somewhat lower concentrations in the effluent but at the expense of greater land area.

Effects of Loading Rate

The raw sewage plots were operated at two different loading rates - approximately 2.5 cm (one inch) per day during Phase I and 5.4 cm (2.1 inches) per day during Phase II. Loading at the higher rate did not seem to greatly affect removal of BOD_5 or suspended solids. The higher hydraulic loading rate did result in higher concentrations of total organic carbon and ammonia nitrogen in the plot effluent. Refer to Tables 12 and 15 for these data.

Even the higher loading rate resulted in very reliable treatment and high quality effluent. The 5.4 cm (2.1 inches) per day hydraulic loading rate and associated BOD loading seemed in no way to harm the grass cover crop. Growth was actually encouraged by the higher loading.

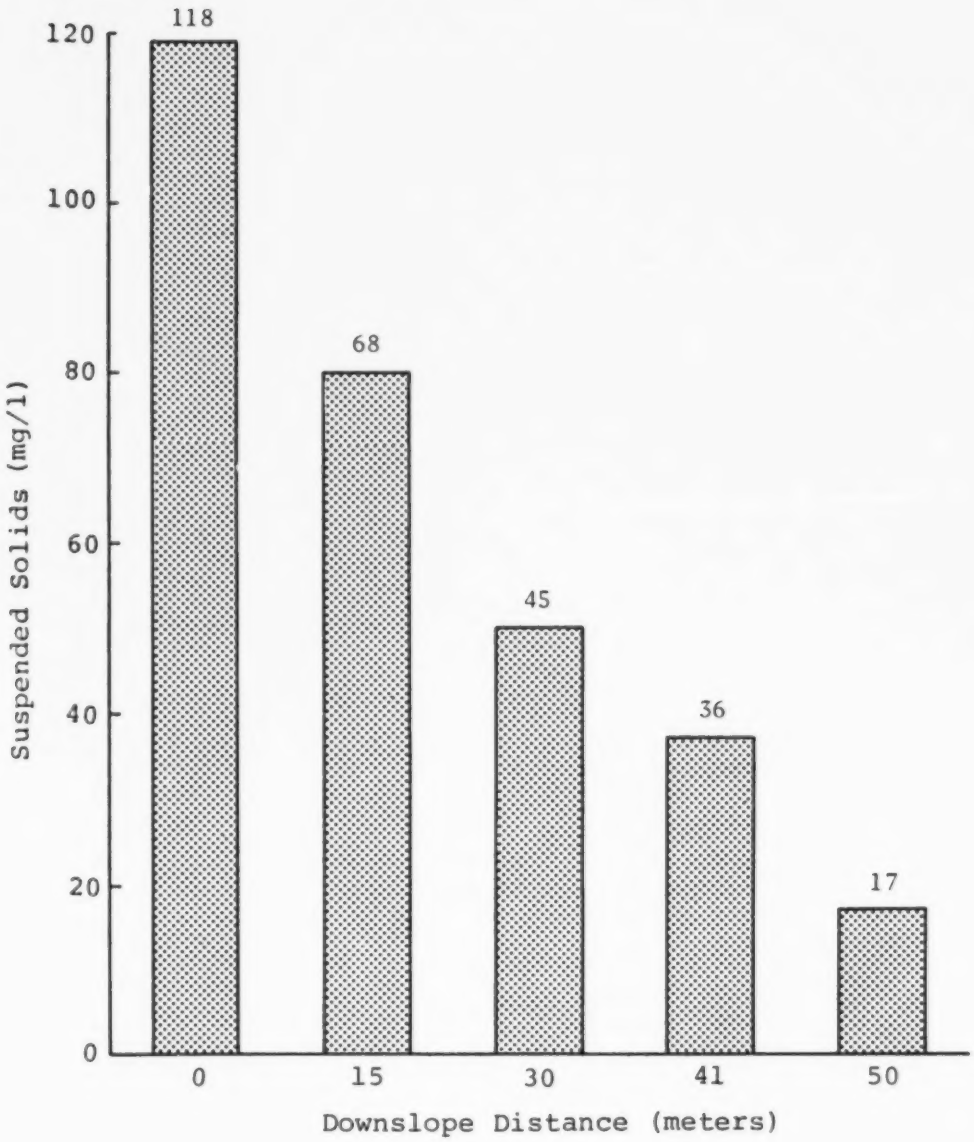

Figure 11. Suspended Solids Profile
Raw Sewage Application

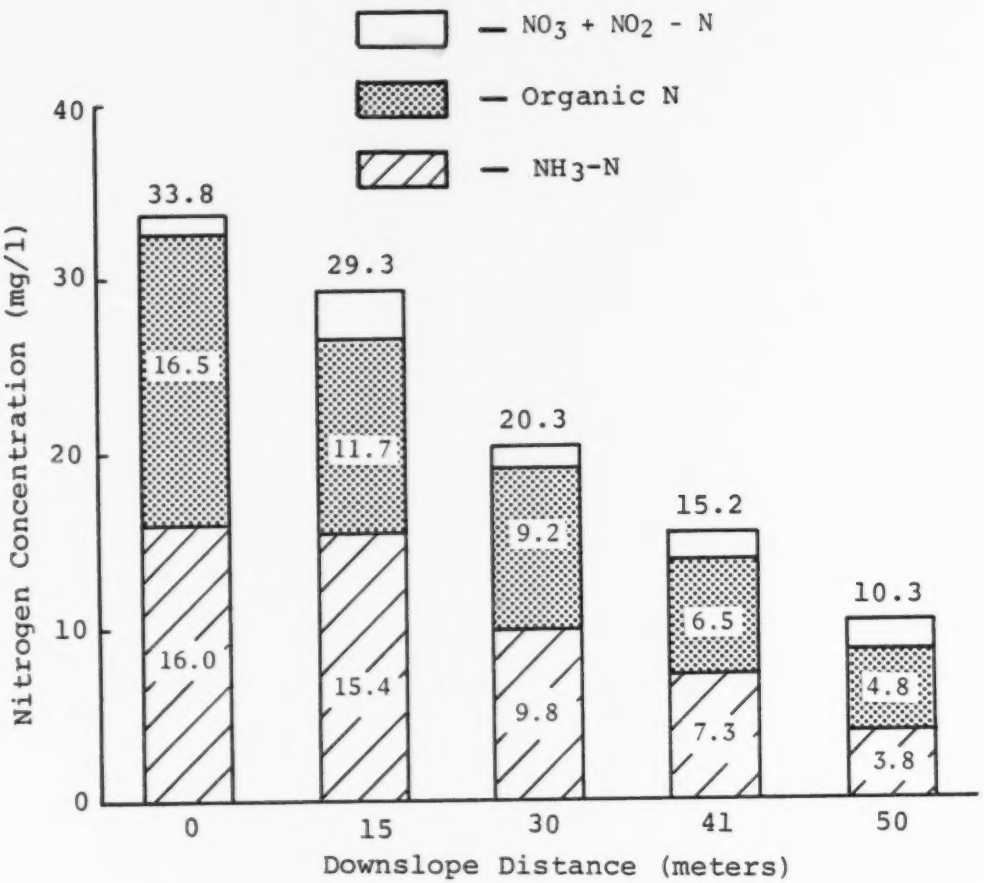

Figure 12. Total Nitrogen Profile
Raw Sewage Application

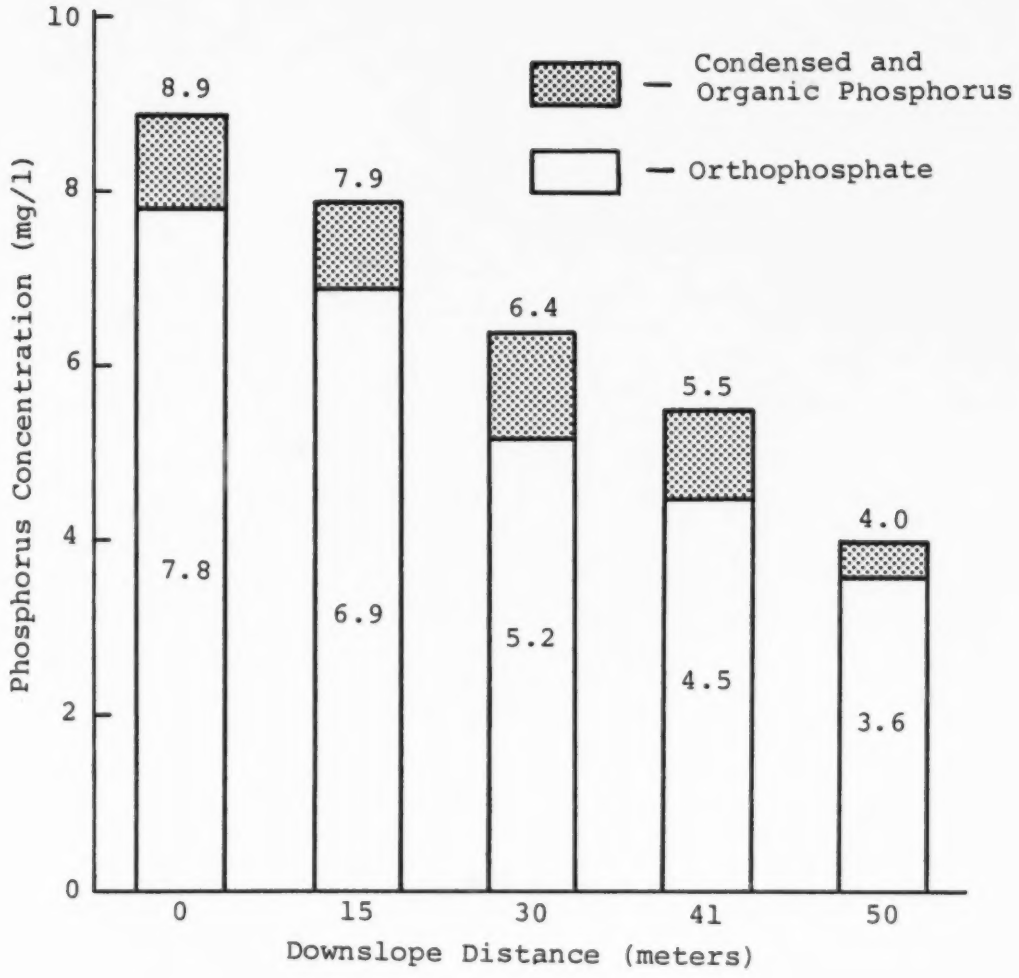

Figure 13. Total Phosphorus Profile
Raw Sewage Application

Feasibility of Treating Comminuted Raw Sewage

The results of the Easley Project indicate that overland flow for treatment of comminuted raw sewage is entirely feasible in a region such as piedmont South Carolina where a mild climate with high rainfall prevails. The effluent was consistently of high quality - better than typical secondary effluent. There were no complaints of odors or other nuisance conditions.

It would appear very feasible to consider overland flow treatment of comminuted raw sewage or screened raw sewage where the regulatory agencies would allow its use.

TREATMENT OF LAGOON EFFLUENT

Overland flow treatment successfully polished faultative lagoon effluent at the Easley Project. Table 40 contains a summary of the results from the lagoon plots over the entire project period. The mean concentration of BOD_5 in the lagoon plot effluent was 14 mg/l for a mean removal of 55 percent on a concentration basis. The mean concentration of suspended solids in the plot effluent was 41 mg/l representing removal of 45 percent. It should be noted that some early samples contained eroded soil particles which increased the suspended solids concentration. Also, the effluent suspended solids concentration was higher during the high loading on plots L1 through L4 during Phase II. When the hydraulic loading rate was reduced to 3.6 cm (1.4 inch) per day during Phase III the suspended solids concentration in the plot effluent decreased. The higher hydraulic loading appeared to increase velocity and turbulence and encourage algal cells to move through and off the plots along with the treated water.

About 23 percent of the total organic carbon in lagoon effluent was removed on the plots along with 34 percent of the total phosphorus and 67 percent of total nitrogen.

These results show that polishing of facultative lagoon effluent can be successfully accomplished by overland flow. The algal cells produced in the lagoon can cause a problem with suspended solids in the plot effluent. This is the major concern raised by the Easley Project results with respect to treating lagoon effluent.

Effects of Flow Distance

Profile studies were also performed for the lagoon effluent plots. Samples were collected 7.6 meters (25 feet), 15 meters (50 feet), 23 meters (75 feet), 30 meters (100 feet), 38 meters (125 feet), and 46 meters (150 feet) downslope on one or more lagoon effluent plots on 10 different dates. Means were computed for each downslope distance. Figure 14 is a profile plot of the BOD_5 means. BOD_5 appears to decline over the entire plot length. Greater plot lengths would probably have reduced the effluent BOD_5 still further, although the last 16 meters (50 feet) resulted in only a decrease of

Table 40: Summary of Performance of Lagoon Effluent Plots from January 1979 through September 1981

Parameter	Lagoon Effluent			Lagoon Plot Effluent			
	Mean Conc. (mg/1)	Range (mg/1)	# of Samples	Mean Conc. (mg/1)	Range (mg/1)	# of Samples	Conc. Removal (%)
BOD	31	16-80	45	14	9-30	63	55
Suspended Solids	74	26-143	50	41	5-152*	99	45
Total Organic Carbon	60	37-84	33	46	20-61	56	23
Total Phosphorus (as P)	35	2.1-5.5	32	2.3	0.6-4.2	66	34
Total Nitrogen (as N)	13	9.7-17.3	10	4.3	3.2-14.0	48	67
Ammonia Nitrogen (as N)	0.48	0.02-3.6	42	0.16	0.01-0.49	69	67

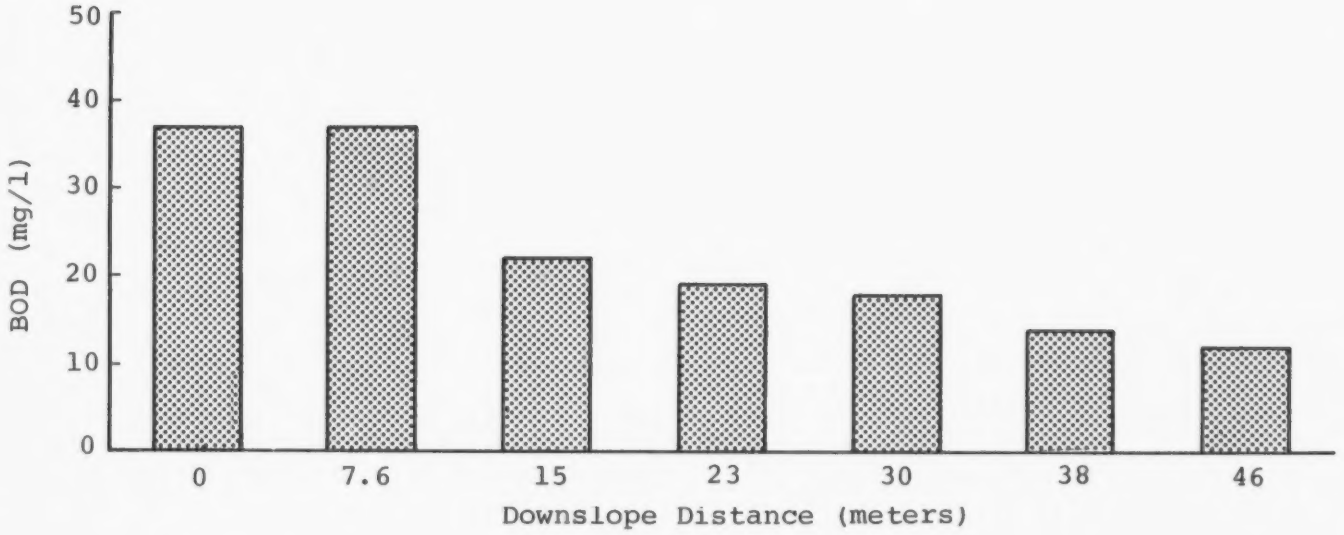

Figure 14. BOD Profile - Lagoon Effluent Application

6 mg/l (from 18 mg/l to 12 mg/l). Figure 15 is a graph of suspended solids at different distances down the slope. The results are very similar to the BOD_5 results - gradual reduction in suspended solids concentration as the lagoon effluent wastewater moves down the slope. Removal appears to be continuing throughout the entire plot length. Algal cells produced in the lagoon seemed to be the major form of suspended solids in plot effluent upon microscopic examination of the solids filtered out of plot effluent samples.

Figure 16 is a plot of total organic carbon concentration vs. plot length. Much of the TOC passes through the overland flow plots. This is probably due to two different factors. One cause is the relatively refractory dissolved organic compounds produced within the lagoon. Another factor is the persistence of many algal cells in flowing with the wastewater and leaving the plot. Thus, the dissolved organic carbon is largely resistant to microbial attack and many of the algal cells are resistant to sedimentation. Therefore, only about 28 percent of the total organic carbon in the lagoon effluent was removed on the plots in the profile studies.

Feasibility of Treating Facultative Lagoon Effluent

The experience at the Easley Project with overland flow treatment of facultative lagoon effluent indicates that successful polishing can be achieved. BOD_5 and suspended solids can be reduced by about 50 percent. Over 20 percent of the total organic carbon can be removed. Nutrient removals from lagoon effluent are significant. Over 30 percent of total phosphosus and more than 65 percent of total nitrogen were removed with 46 meter (150 feet) plots.

The problem that was brought out during the Easley Project is the difficulty of removing many of the algae which are produced in the lagoon and are present in lagoon effluent. At high hydraulic loading rates many of these algae, especially unicellular ones, move along with the water and leave the plot with the overland flow effluent. This can make the overland flow effluent very green to the observer and yield high values in suspended solids determinations. This problem can result in reducing the allowable hydraulic loading rates for treating lagoon effluent by overland flow to values comparable to those for comminuted raw sewage, or else risk excessive suspended solids concentrations in the final effluent. In some cases algae solids may result in excessive suspended solids concentrations even at low hydraulic loading rates.

Further research is needed to resolve this problem and make overland flow an excellent alternative for polishing the effluent from the many existing facultative lagoons.

COMPARISON OF SYSTEM COMPONENTS

Table 41 contains the means for BOD_5, suspended solids, TOC, total phosphorous, total nitrogen and ammonia nitrogen measurements made over the entire project operation. Note that when lagoon treatment is combined with overland flow and percent removal computed on the basis of raw sewage concentrations, the removal of organic matter and nutrients is excellent. It

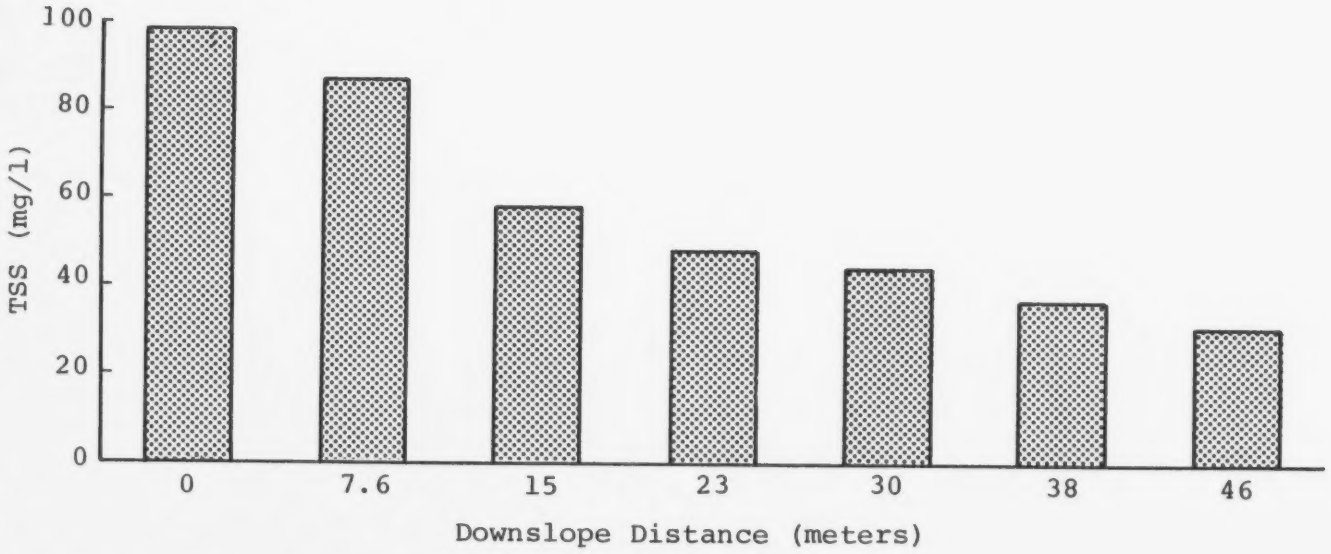

Figure 15. Suspended Solids Profile - Lagoon Effluent

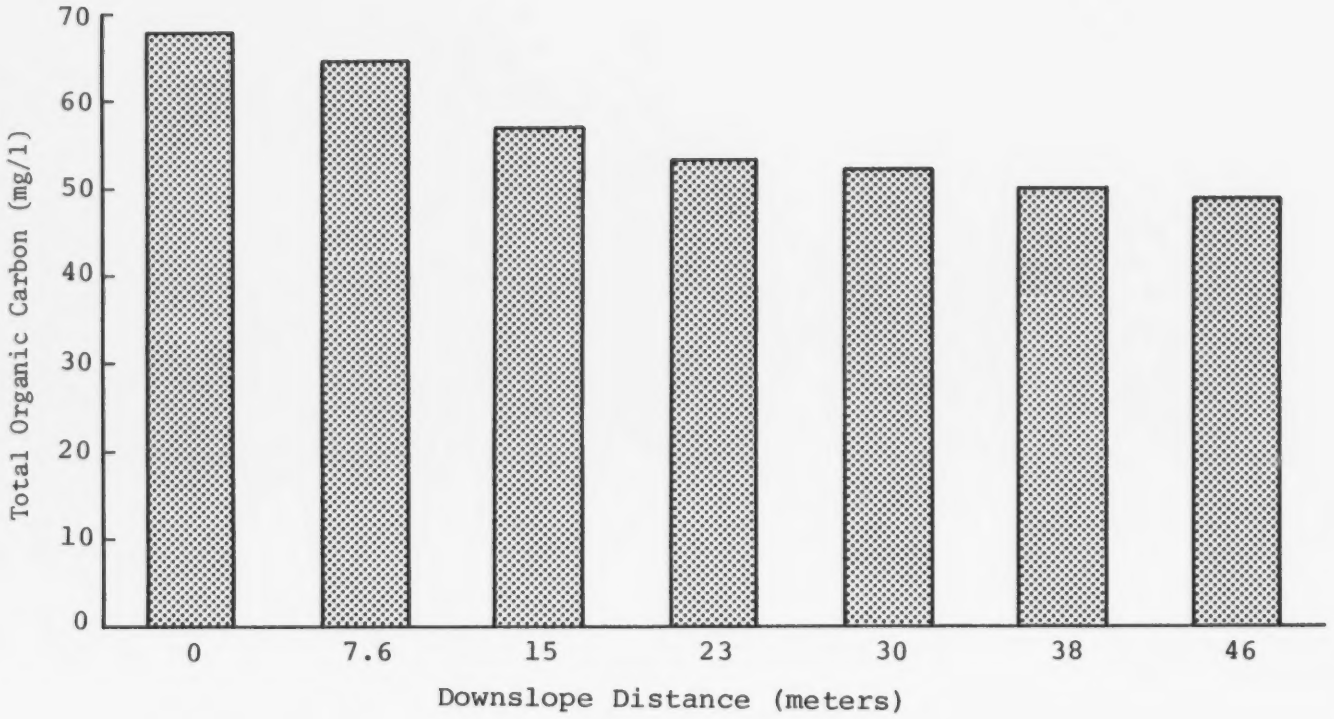

Figure 16. Total Organic Carbon Profile - Lagoon Effluent Application

Table 41: Mean Performance of the Easley, S.C. Project
January 1979 through September 1981

Parameter	Raw Sewage	Lagoon Effluent		Overland Flow System				Lagoon and Overland Flow
				Lagoon Effluent Plots		Raw Sewage Plots		
	Conc. (mg/l)	Conc. (mg/l)	Removal (%)	Conc. (mg/ℓ)	Removal (%)	Conc. (mg/ℓ)	Removal (%)	Removal (%)
BOD	157	31	80	14	55	21	87	91
TSS	161	74	54	41	46	24	85	74
TOC	95	60	37	46	23	36	62	52
Total P	8.0	3.5	56	2.3	34	4.0	50	71
Total N	32	13	59	4.3	67	12	62	87
NH_3 N	18	0.42	97	0.16	67	3.0	83	99

may be easier to compare system components performance when the data from Table 41 are used to prepare graphs such as Figure 17. In Figure 17 the mean BOD_5 concentrations for raw sewage, overland flow effluent with raw sewage application, lagoon effluent, and overland flow effluent with lagoon effluent applications are presented. It can be seen that both overland flow systems produced an effluent lower in BOD_5 than did the lagoon. Note, however, that overland flow polishing of lagoon effluent resulted in a lower mean concentration of BOD_5 than did overland flow treatment of comminuted raw sewage.

Figure 18 is a similar bar graph of mean suspended solids concentrations in the various waste streams. Overland flow treatment of comminuted raw sewage resulted in the lowest mean concentration of suspended solids - 24 mg/l compared to 41 mg/l for effluent from the overland flow system receiving lagoon effluent. Mention has already been made of the difficulty of removing algae cells from the lagoon effluent.

Mean concentrations of total phosphorous are plotted in Figure 19. There is some advantage of lagoon treatment followed by overland flow for removing total phosphorous. The mean total phosphorous concentration for overland flow treatment of lagoon effluent was 2.3 mg/l compared to 4.0 mg/l for overland flow treatment of comminuted raw sewage.

Total nitrogen removal was similar to total phosphorous. See Figure 20. Overland flow treatment of lagoon effluent produced a wastewater with a mean total nitrogen concentration of 4.3 mg/l compared to 12 mg/l for the overland flow treatment of raw sewage. It should be noted that lagoon treatment of raw sewage resulted in similar removals of phosphorous and nitrogen to those resulting from overland flow treatment of comminuted raw sewage.

The choice to treat comminuted raw sewage or facultative lagoon effluent should probably depend upon the nature of existing lagoons, their loading rate, and an economic comparison of the two possibilities as well as the possibility of approval by the permitting agency. There is probably a better pretreatment alternative before overland flow than use of a facultative lagoon. However, the addition of overland flow to existing lagoon systems could result in excellent treatment if algal cells were removed more effectively by overland flow.

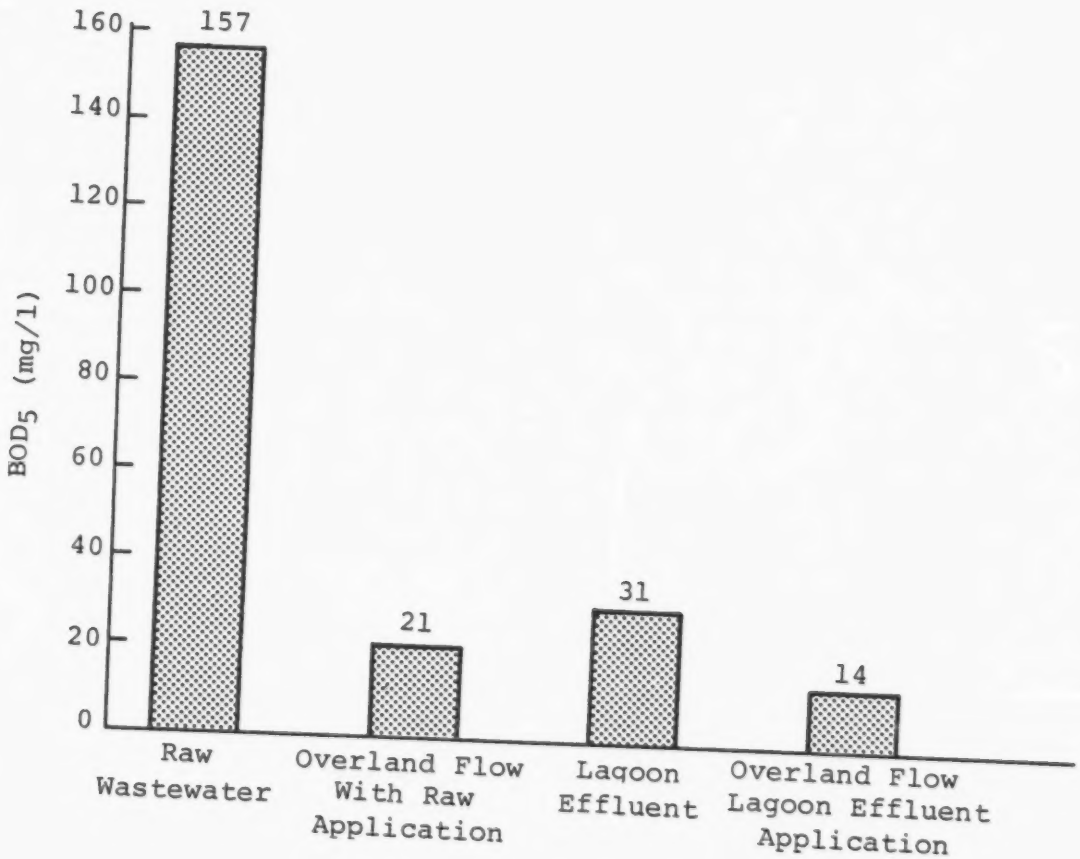

Figure 17. System Performance - BOD_5

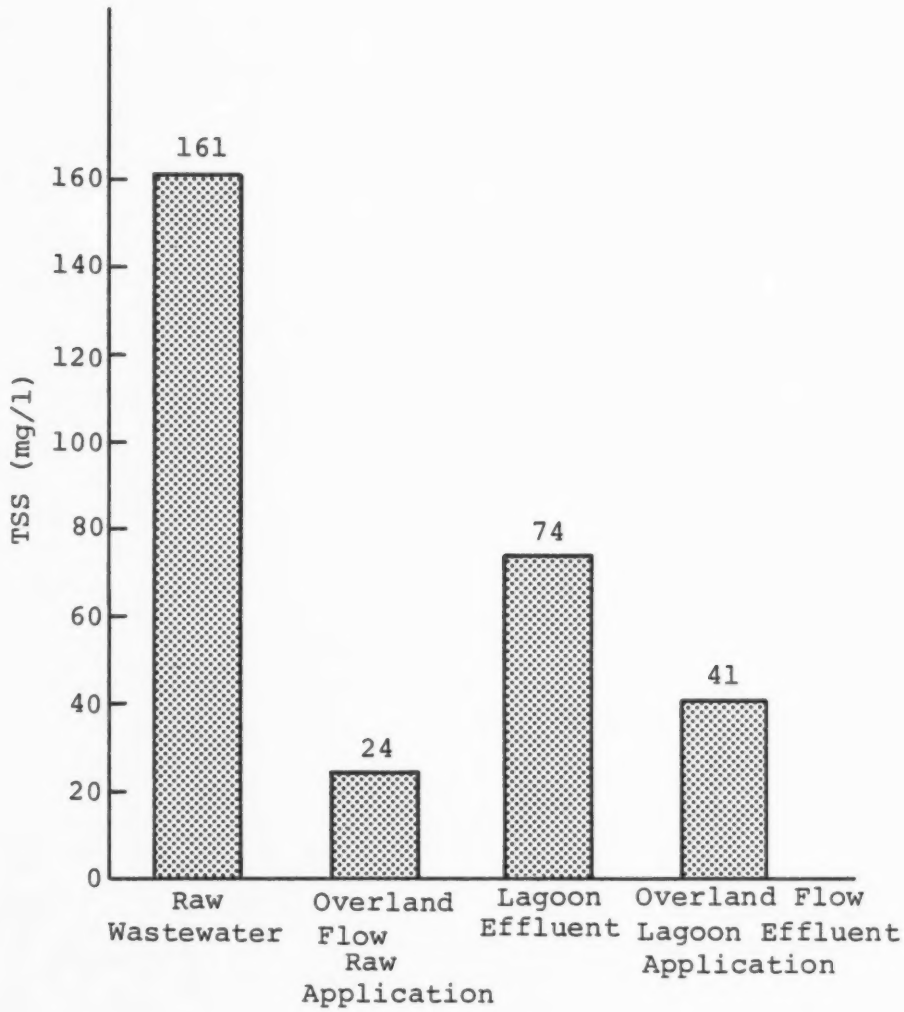

Figure 18. System Performance - Suspended Solids

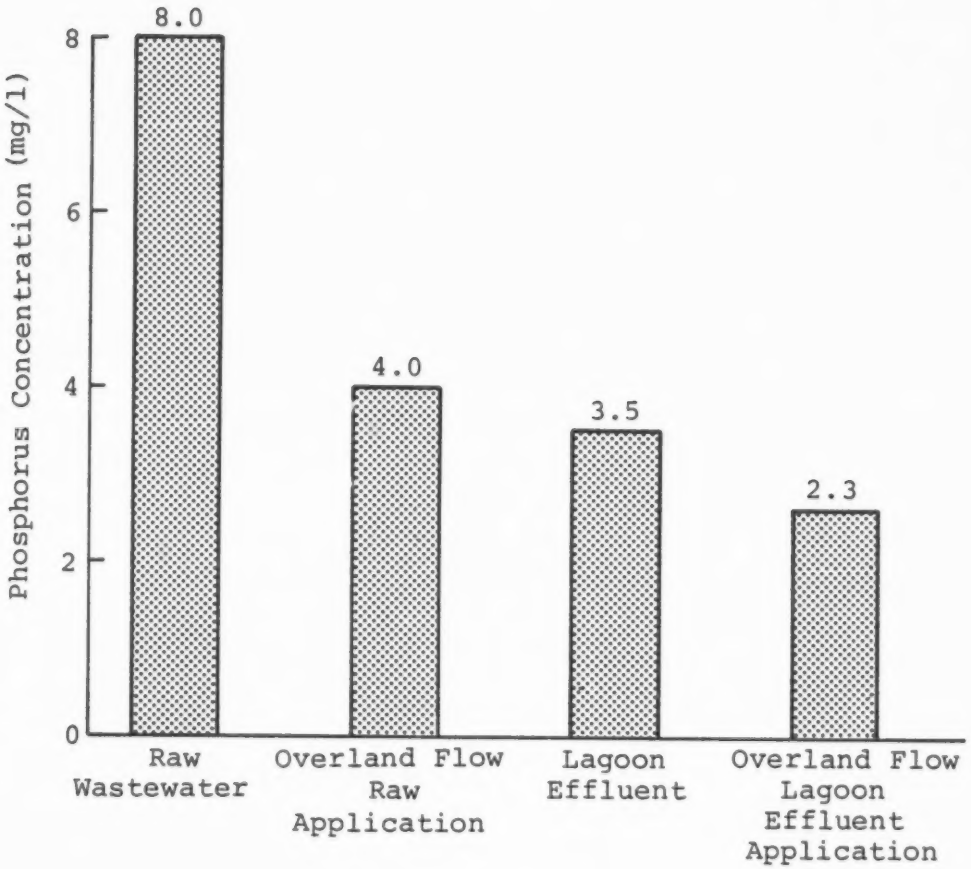

Figure 19. System Performance - Total Phosphorus

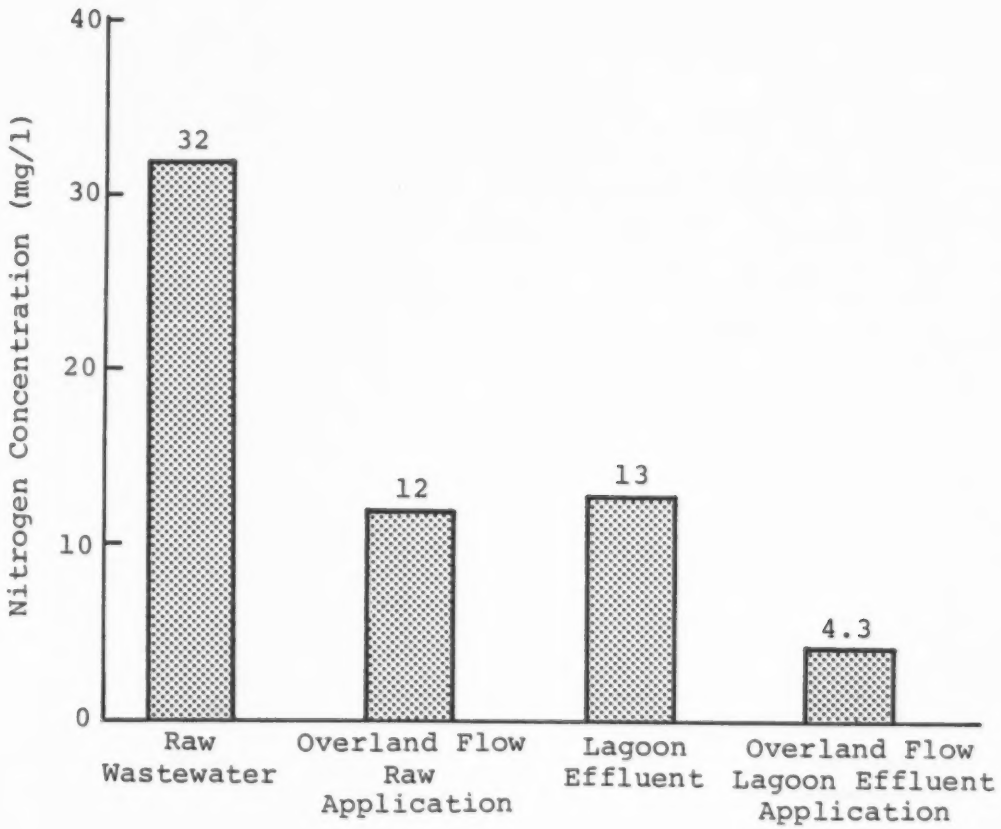

Figure 20. System Performance
Total Nitrogen

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APPENDIX

Table A-1 : Raw Data for the Easley Overland Flow System

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
01-11-79	RS	190	-	-	-	-	-	122	-	-	-	-	-	-	4.4	4.2
	LEFF	21	-	-	-	-	-	36	-	-	-	3.6	-	-	3.8	3.4
	TSE	13	-	-	-	-	-	50	-	-	-	2.8	-	-	3.0	3.0
	RST	50	-	-	-	-	-	122	-	-	-	8.4	-	-	3.9	3.9
01-17-79	RS	255	-	-	-	-	-	266	-	-	-	-	-	-	-	-
	LEFF	25	-	-	-	-	-	46	-	-	-	-	-	-	-	-
	RST	46	-	-	-	-	-	90	-	-	-	-	-	-	-	-
01-24-79	RS	110	-	-	-	10	-	68	-	-	-	11.5	-	-	-	-
	LEFF	24	-	-	-	21	-	40	-	-	-	1.20	-	-	-	-
	TSE	14	-	-	-	10	-	36	-	-	-	0.70	0.29	-	-	-
	RST	24	-	-	-	11	-	36	-	-	-	<0.02	<0.02	-	-	-

* No Lagoon Effluent Applied

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
01-31-79	RS	170	-	-	-	24	-	94	84	-	-	19.6	-	-	5.5	3.2
	LEFF	30	-	-	-	18	-	70	50	-	-	0.45	-	-	3.8	2.8
	TSE	20	-	-	-	22	-	94	52	-	-	-	-	-	2.8	2.4
	CT 4	23	-	-	-	26	-	-	-	-	-	-	-	-	2.9	2.4
	CT 5	23	-	-	-	22	-	-	-	-	-	-	-	-	3.3	3.1
	CT 6	26	-	-	-	34	-	-	-	-	-	-	-	-	2.9	2.2
	L1	30	-	-	-	26	-	128	-	-	-	0.32	-	-	3.4	2.6
	L2	20	-	-	-	24	-	52	-	-	-	0.06	-	-	3.2	3.2
	L3	26	-	-	-	23	-	50	-	-	-	-	-	-	-	2.3
	L4	20	-	-	-	20	-	46	-	-	-	-	-	-	3.7	2.3
	L5	21	-	-	-	21	-	42	-	-	-	-	-	-	2.5	2.2
	L7	21	-	-	-	20	-	128	-	-	-	-	-	-	3.5	2.9
	L9	20	-	-	-	21	-	112	-	-	-	-	-	-	2.6	2.2
	L10	28	-	-	-	22	-	152	-	-	-	-	-	-	3.5	3.1

TABLE A-1. cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)			Nitrogen(mg-N/l)				Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
02-14-79	RS	160	-	-	-	57	-	130	120	-	-	17.5	-	-	-	-
	LEFF	16	-	-	-	46	-	60	60	-	-	0.20	-	-	-	-
	TSE	15	-	-	-	41	-	64	46	-	-	0.04	0.50	-	-	-
	L2	-	-	-	-	-	-	-	-	-	-	-	0.41	-	-	-
	L4	-	-	-	-	-	-	-	-	-	-	-	0.41	-	-	-
02-21-79	RS	130	-	-	-	12	-	66	40	-	-	3.57	0.32	-	1.0	-
	LEFF	26	-	-	-	26	-	62	62	-	-	0.08	0.48	-	3.0	-
	TSE	5	-	-	-	28	-	36	22	-	-	0.04	0.26	-	0.5	-
	RST	3	-	-	-	7	-	-	-	-	-	0.03	0.26	-	0.5	-
	L4	16	-	-	-	17	-	24	-	-	-	0.01	0.26	-	1.6	-
	L5	13	-	-	-	17	-	28	-	-	-	0.01	0.32	-	1.6	-
	L7	9	-	-	-	7	-	8	-	-	-	0.01	0.27	-	0.6	-
	L9	11	-	-	-	14	-	16	-	-	-	0.02	0.32	-	1.0	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
02-28-79	RS	160	45	115	-	30	-	108	76	-	-	11.2	-	-	11.9	9.6
	LEFF	-	11	-	-	15	-	50	50	-	-	0.13	-	-	3.2	2.7
	TSE	6	6	0	-	17	-	48	38	-	-	0.07	0.21	-	2.3	2.0
	CT 1	-	9	-	-	16	-	54	-	-	-	0.03	0.47	-	2.0	1.9
	CT 2	-	11	-	-	19	-	120	-	-	-	0.03	0.73	-	2.4	2.4
	L3	-	-	-	-	-	-	-	-	-	-	0.03	0.73	-	-	-
	L10	-	-	-	-	-	-	-	-	-	-	0.03	0.47	-	-	-
03-07-79	RS	135	66	69	-	35	-	52	52	-	-	12.0	-	-	5.3	3.9
	LEFF	24	12	12	-	25	-	42	42	-	-	0.22	-	-	2.9	2.5
	TSE	13	8	5	-	22	-	34	34	-	-	0.19	0.28	-	2.9	2.6
	RST	-	21	-	-	22	-	24	-	-	-	1.96	0.52	-	4.3	3.5
	R1	-	26	-	-	26	-	32	-	-	-	4.76	0.64	-	5.1	4.3
	R2	-	23	-	-	21	-	26	-	-	-	0.19	0.45	-	3.9	3.5
	R3	-	24	-	-	24	-	16	-	-	-	1.26	0.59	-	3.7	3.2
	L4	-	7	-	-	22	-	42	-	-	-	0.03	0.17	-	2.5	2.2
	L5	-	10	-	-	23	-	40	-	-	-	0.04	0.14	-	2.7	2.1
	L7	-	8	-	-	18	-	44	-	-	-	0.03	0.20	-	2.8	2.6
	L9	-	7	-	-	17	-	38	-	-	-	0.04	0.16	-	2.5	2.2

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
03-14-79	RS	270	58	212	-	29	-	252	238	-	-	12.0	-	-	-	6.0
	LEFF	36	6	30	-	19	-	56	54	-	-	0.05	-	-	-	2.6
	TSE	15	7	8	-	22	-	26	26	-	-	0.17	0.35	-	-	2.1
	RST	-	35	-	-	21	-	36	-	-	-	2.59	0.46	-	-	3.9
	CT 1	-	14	-	-	23	-	-	-	-	-	0.81	0.36	-	-	3.0
	CT 2	-	11	-	-	21	-	-	-	-	-	0.70	0.36	-	-	2.8
03-28-79	RS	103	46	57	-	50	-	138	126	-	-	-	-	-	-	-
	LEFF	19	4	15	-	25	-	38	38	-	-	-	-	-	-	-
	TSE	15	3	12	-	26	-	36	30	-	-	-	-	-	-	-
	RST	-	3	-	-	26	-	22	22	-	-	-	-	-	-	-
	CT 1	-	3	-	-	27	-	20	20	-	-	-	-	-	-	-
	CT 2	-	2	-	-	27	-	22	22	-	-	-	-	-	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)			Nitrogen(mg-N/l)				Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
04-06-79	RS	115	35	80	-	16	-	76	76	-	-	6.02	-	-	4.1	2.6
	LEFF	18	7	11	-	19	-	42	42	-	-	0.18	-	-	2.8	2.3
	TSE	9	5	4	-	22	-	30	6	-	-	0.03	0.40	-	2.9	2.4
	CT 1	-	8	-	-	21	-	16	16	-	-	0.02	1.01	-	2.1	1.5
	CT 2	-	13	-	-	23	-	20	20	-	-	0.03	1.40	-	2.8	2.3
	R1	-	15	-	-	22	-	20	20	-	-	0.47	0.17	-	4.4	3.3
	R2	-	12	-	-	17	-	12	12	-	-	0.10	0.15	-	3.1	2.4
	L1	-	6	-	-	21	-	32	-	-	-	0.12	0.40	-	1.8	1.4
	L2	-	6	-	-	18	-	32	-	-	-	0.02	0.22	-	2.3	1.6
	L3	-	6	-	-	21	-	28	-	-	-	0.06	0.14	-	1.5	1.0
	L4	-	6	-	-	18	-	-	-	-	-	0.01	0.15	-	1.8	1.4
	L5	-	5	-	-	19	-	20	-	-	-	0.02	0.17	-	1.9	1.5
	L6	-	8	-	-	29	-	22	-	-	-	0.07	0.14	-	1.2	0.7
	L7	-	5	-	-	19	-	20	-	-	-	0.03	0.20	-	1.8	1.5
	L8	-	7	-	-	24	-	36	-	-	-	0.01	0.17	-	1.9	1.5
	L9	-	5	-	-	20	-	34	-	-	-	0.03	0.29	-	1.6	1.2
	L10	-	5	-	-	24	-	16	-	-	-	0.03	0.50	-	2.3	1.8

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
04-11-79	RS	265	93	172	-	49	-	-	-	-	-	10.9	-	-	9.6	7.1
	LEFF	25	6	19	-	14	-	-	-	-	-	0.52	-	-	3.3	3.0
	TSE	11	6	5	-	22	-	-	-	0.44	0.19	0.01	0.25	-	2.1	1.7
	CT 1	-	4	-	-	22	-	-	-	0.23	0.01	0.01	0.22	-	2.0	1.6
	CT 2	-	7	-	-	14	-	-	-	0.37	0.23	0.02	0.14	-	2.1	1.8
04-18-79	RS	-	-	-	-	-	-	134	-	-	-	-	-	-	-	-
	LEFF	27	8	19	-	17	-	50	50	-	0.12	0.02	-	-	2.8	2.2
	TSE	6	7	-	-	24	-	22	22	0.44	0.12	0.01	0.31	-	1.7	1.4
	CT 1	-	10	-	-	16	-	40	-	0.24	0.07	0.01	0.17	-	1.8	1.4
	CT 2	-	7	-	-	19	-	32	-	0.24	0.06	0.01	0.18	-	1.9	1.3
	L2	-	10	-	-	23	-	44	-	0.34	0.08	0.01	0.26	-	2.0	1.3
	L3	-	10	-	-	25	-	40	-	0.36	0.08	0.01	0.28	-	1.6	1.2
	L4	-	8	-	-	20	-	36	-	0.25	0.07	0.02	0.18	-	1.6	1.2
	L5	-	9	-	-	22	-	30	-	0.38	0.10	0.01	0.28	-	1.7	1.2
	L7	-	8	-	-	25	-	24	-	0.24	0.08	0.01	0.17	-	1.8	1.4
	L8	-	7	-	-	23	-	30	-	0.29	0.11	0.03	0.18	-	1.9	1.5
	L9	-	8	-	-	25	-	38	-	0.21	0.07	0.01	0.14	-	1.6	1.2
	L10	-	10	-	-	22	-	38	-	0.23	0.06	0.01	0.17	-	2.2	1.8

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
04-25-79	RS	-	-	-	-	28	-	464	384	-	14.0	9.38	-	-	-	-
	LEFF	-	-	-	-	18	-	60	60	-	2.00	0.91	-	-	3.1	2.6
	TSE	-	-	-	-	27	-	30	30	2.24	2.10	0.02	0.14	-	1.8	1.5
	CT 1	-	-	-	-	27	-	36	-	2.01	1.85	0.02	0.16	-	1.9	1.5
	CT 2	-	-	-	-	25	-	24	-	1.54	1.40	0.02	0.14	-	1.8	1.5
05-09-79	RS	90	40	50	-	21	-	96	96	-	32.9	24.5	-	-	5.1	3.6
	LEFF	28	5	23	-	22	-	50	50	-	2.24	0.98	-	-	3.1	2.2
	TSE	13	6	7	-	26	-	20	20	1.8	1.40	0.14	0.39	-	1.4	1.0
05-15-79	RS	208	65	143	-	25	-	262	252	-	12.6	5.46	-	-	-	4.4
	LEFF	40	11	29	-	20	-	72	72	-	1.50	0.32	-	-	2.8	1.6
	TSE	20	12	8	-	23	-	30	30	0.66	0.52	0.03	0.14	-	1.5	0.9
	L7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
05-23-79	RS	140	50	90	53	23	30	102	102	-	17.8	10.1	-	-	-	4.6
	LEFF	80	10	70	-	-	-	120	120	-	3.78	0.55	-	-	3.9	1.1
	TSE	23	10	13	28	19	9	40	40	2.00	1.75	0.02	0.25	-	1.2	0.4
	CT 1	-	8	-	-	20	-	48	48	0.99	0.73	0.01	0.26	-	1.3	0.5
	CT 2	-	8	-	-	22	-	48	48	1.06	0.92	0.01	0.14	-	1.3	0.4
	L2	-	8	-	-	13	-	44	-	1.07	0.76	0.01	0.31	-	1.3	0.4
	L3	-	11	-	-	19	-	30	-	0.67	0.48	0.02	0.19	-	0.9	0.3
	L4	-	7	-	-	18	-	56	-	0.73	0.45	0.01	0.28	-	1.5	0.5
	L5	-	11	-	-	19	-	48	-	1.84	1.57	0.02	0.27	-	1.5	0.6
	L7	-	8	-	-	17	-	32	-	2.33	2.10	0.01	0.23	-	0.9	0.3
	L8	-	10	-	-	23	-	42	-	2.91	2.66	0.02	0.25	-	1.5	0.6
	L9	-	9	-	-	18	-	56	-	-	-	0.01	0.25	-	1.6	0.4
	L10	-	8	-	-	23	-	54	-	1.50	1.29	0.02	0.21	-	1.8	0.7
05-30-79	RS	172	50	122	-	-	-	134	132	-	-	10.9	-	-	-	9.3
	LEFF	32	9	23	-	-	-	56	56	-	-	0.14	-	-	2.1	1.3
	TSE	-	12	-	-	-	-	58	58	-	-	0.02	0.20	-	1.7	0.5
	CT 1	-	11	-	-	-	-	46	46	-	-	0.03	0.27	-	1.5	0.6
	CT 2	-	8	-	-	-	-	176	176	-	-	0.02	0.20	-	1.7	0.5

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
07-25-79	RS	-	40	-	63	23	40	96	94	-	24.5	10.6	-	-	-	-
	R1-50	-	24	-	37	18	19	34	34	-	18.6	10.6	-	-	-	-
	R1-100	-	7	-	31	15	16	28	28	15.9	13.7	10.6	2.24	-	-	-
	R1	-	6	-	21	13	8	18	18	-	-	4.76	1.37	-	-	-
08-01-79	RS	108	25	83	68	28	40	59	59	-	23.8	9.52	-	-	8.1	6.8
	LEFF	18	2	16	41	24	17	26	26	-	7.00	0.73	-	-	2.7	2.1
	TSE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R1-50	44	11	33	38	20	18	21	21	15.5	14.7	7.56	0.76	-	6.8	5.1
	R1-100	-	12	-	38	20	18	19	19	18.1	17.5	7.84	0.60	-	6.6	5.4
	R1-150	-	-	-	30	19	11	47	13	10.2	9.52	4.76	0.69	-	4.7	4.1
	R1	17	6	11	30	21	9	6	6	6.92	6.02	2.28	0.90	-	3.9	3.6
	R2-50	56	17	39	40	22	18	13	13	18.1	16.8	8.96	1.32	-	6.3	5.0
	R2-100	25	5	20	38	24	14	34	34	10.8	9.80	3.08	1.02	-	4.5	3.6
	R2-150	-	-	-	39	20	19	40	40	10.2	9.24	2.80	1.02	-	4.2	3.4
	R2	14	3	11	34	25	9	9	9	6.92	5.60	1.29	1.32	-	3.2	2.4

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
08-15-79	RS	228	69	159	204	46	158	380	334	-	40.6	18.2	-	-	11.2	8.5
	LEFF	38	4	34	60	31	29	50	46	-	10.9	0.02	-	0.03	3.5	2.4
	TSE	16	8	8	41	30	11	10	2	3.11	1.99	1.01	1.04	0.11	2.8	2.2
	LPRO	27	4	23	49	33	16	18	18	3.41	3.08	0.02	0.27	0.06	2.2	1.3
	R1-50	78	17	61	56	23	33	68	50	20.5	19.2	12.6	1.26	0.07	6.7	5.8
	R1-100	55	11	44	45	23	22	32	24	17.3	16.1	10.9	1.01	0.14	5.9	4.9
	R1-150	42	9	33	45	22	23	68	22	-	-	8.12	1.34	0.19	5.3	4.5
	R1	27	5	22	34	24	10	6	6	5.56	4.06	3.08	1.37	0.13	3.3	3.0
	R2-50	66	16	50	52	25	27	24	12	-	-	16.8	1.12	0.14	6.0	5.6
	R2-100	42	9	33	38	26	12	20	18	-	-	7.56	1.26	0.11	4.7	3.9
	R2-150	30	8	22	42	23	19	18	8	-	-	5.04	1.01	0.12	3.7	3.1
	R2	25	6	19	35	26	9	0	0	3.73	2.66	1.68	0.98	0.09	2.6	2.2

Note: LPRO = Runoff from L2, L4 and L5

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
08-22-79	RS	154	37	117	82	26	56	128	106	-	30.8	14.7	-	0.20	4.7	4.2
	LEFF	20	3	17	47	28	19	36	36	-	7.00	1.54	-	0.06	2.5	1.9
	TSE	8	3	5	34	31	3	14	14	3.64	3.22	0.67	0.28	0.14	2.0	1.6
	LPRO	16	3	13	39	31	8	26	24	3.99	3.64	0.03	0.22	0.13	1.6	1.5
	R2-50	68	21	47	56	27	29	80	56	24.9	23.8	11.2	1.06	0.08	5.1	4.5
	R2-100	62	20	42	49	25	24	44	42	22.7	21.7	10.6	0.89	0.07	4.8	4.2
	R2-135	35	9	26	34	23	11	34	32	13.1	12.6	8.12	0.36	0.14	4.1	3.4
	R2	24	8	16	29	23	6	8	8	7.58	6.58	3.64	0.89	0.11	2.9	2.9
	R3-50	63	23	40	53	22	31	50	50	23.0	21.7	13.4	1.23	0.08	4.7	4.8
	R3-100	42	16	26	45	26	19	50	38	19.7	18.9	10.6	0.76	0.06	3.6	3.5
	R3-135	29	14	15	41	25	16	44	20	11.3	10.6	5.88	0.59	0.07	2.8	2.3
	R3	32	12	20	34	24	10	20	20	7.30	6.58	3.08	0.64	0.08	3.0	2.5

Note: LPRO = Runoff from L2, L4, L5, L7 and L9

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
08-28-79	RS	166	63	103	90	31	59	154	136	-	22.9	16.3	-	0.18	6.1	4.4
	LEFF	31	3	28	50	35	15	46	46	-	2.36	0.07	-	0.06	3.0	2.1
	TSE	10	5	5	37	31	6	14	12	6.54	4.29	1.41	2.17	0.08	2.7	2.3
	LPRO	15	3	12	40	33	7	18	14	4.90	3.93	0.08	0.87	0.09	1.9	1.4
	R2-50	85	26	59	90	32	58	168	112	18.1	13.9	13.7	4.06	0.09	11.1	8.7
	R2-100	65	23	42	63	25	38	158	106	13.1	11.5	9.96	1.44	0.20	8.1	6.3
	R2-135	38	18	20	39	24	14	28	28	13.2	10.7	8.94	2.31	0.18	6.1	5.4
	R2	27	11	16	30	22	8	16	8	11.0	7.53	5.65	3.22	0.22	4.7	4.3
	R3-50	38	28	10	44	23	21	44	22	20.6	12.0	10.4	8.40	0.22	7.7	6.9
	R3-100	21	14	7	33	21	12	92	24	15.2	9.72	8.71	5.32	0.15	5.7	5.0
	R3-135	18	5	13	29	22	7	106	26	10.3	6.77	5.77	3.36	0.14	4.8	4.3
	R3	13	15	?	27	20	7	6	4	9.49	6.03	3.58	3.36	0.10	3.0	2.5

Note: LPRO = Runoff from L2, L4, L5, L7 and L9

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
09-11-79	RS	225	-	-	44	28	16	178	154	-	33.8	12.9	-	0.59	10.6	8.3
	LEFF	25	-	-	64	27	37	72	68	15.9	15.6	1.47	0.26	0.02	2.5	2.2
	TSE	6	-	-	86	35	51	38	18	8.86	7.63	0.27	1.21	0.02	2.4	2.0
	LPRO	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	1.7
	R1-50	-	-	-	56	28	28	48	42	30.0	26.0	11.2	3.78	0.20	6.1	5.8
	R1-100	-	-	-	47	23	24	48	50	22.2	19.4	9.24	2.66	0.14	5.3	4.6
	R1-135	-	-	-	36	20	16	22	22	16.7	14.3	5.88	2.38	0.02	4.9	4.3
	R1	-	-	-	32	22	10	36	12	6.33	5.72	0.73	0.59	0.02	3.0	2.2
	R2-50	-	-	-	-	27	-	500	312	43.1	41.9	12.0	1.02	0.17	10.1	7.1
	R2-100	-	-	-	39	21	18	200	72	18.5	17.0	5.25	1.46	0.02	4.4	4.3
	R2-135	-	-	-	59	21	38	294	120	15.1	14.1	3.15	0.85	0.15	4.6	4.0
	R2	-	-	-	40	23	17	6	6	9.29	7.86	1.68	1.43	-	3.6	2.8
	R3	-	-	-	30	22	8	12	12	-	6.60	1.40	-	0.02	-	2.1

Note : LPRO = Runoff from L5

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
09-24-79	RS	140	-	-	81	27	54	-	-	34.6	33.8	13.2	0.7	0.06	-	-
	LEFF	26	-	-	52	31	21	-	-	11.7	9.76	0.96	1.86	0.11	-	-
	TSE	11	-	-	50	33	17	-	-	9.76	8.63	0.24	1.09	0.04	-	-
	LPRO	-	-	-	44	33	11	-	-	7.81	7.11	0.11	0.67	0.03	-	-
	R1-50	-	-	-	74	28	46	-	-	32.5	32.0	14.7	0.40	0.09	-	-
	R1-100	-	-	-	57	24	33	-	-	20.3	19.4	7.86	0.85	0.08	-	-
	R1-135	-	-	-	49	26	23	-	-	14.6	13.7	5.37	0.79	0.07	-	-
	R1	-	-	-	46	28	18	-	-	9.77	8.24	0.89	1.46	0.07	-	-
	R2-50	-	-	-	87	31	56	-	-	34.5	33.8	12.8	0.66	0.08	-	-
	R2-100	-	-	-	-	30	-	-	-	39.5	38.3	7.23	1.12	0.08	-	-
	R2-135	-	-	-	-	27	-	-	-	14.5	13.1	5.57	1.31	0.05	-	-
	R2	-	-	-	45	25	20	-	-	9.71	7.86	2.10	1.81	0.04	-	-

Note : 1) BOD - 6 days @ 20 degrees C
2) LPRO = Runoff from L2, L5, L7 and L9

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)			Nitrogen(mg-N/l)				Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
10-02-79	RS	133	-	-	-	-	-	-	-	-	16.8	11.6	-	1.20	8.0	5.8
	LEFF	30	-	-	-	-	-	-	-	-	9.26	0.09	-	0.21	2.1	2.4
	TSE	13	-	-	-	-	-	-	-	-	6.40	0.19	-	0.03	2.2	2.3
	R1	-	-	-	-	-	-	-	-	-	4.47	1.34	-	0.20	3.7	3.5
	R2	-	-	-	-	-	-	-	-	-	5.72	3.26	-	0.19	4.2	3.9
	R3	-	-	-	-	-	-	-	-	-	2.82	0.04	-	0.37	1.4	1.8
10-09-79	RS	258	-	-	91	-	-	50	42	-	17.0	13.4	-	0.66	17.0	11.3
	LEFF	34	-	-	-	29	-	44	42	-	9.49	0.05	-	0.17	3.4	2.5
	TSE	5	-	-	51	29	22	8	2	-	6.93	0.45	-	0.07	3.2	2.9
	LPRO	-	-	-	46	29	17	14	12	-	7.63	0.08	-	0.10	2.5	2.0
	R1-50	-	-	-	74	30	44	40	22	-	18.5	16.8	-	0.20	11.1	8.0
	R1-100	-	-	-	35	24	11	16	14	-	11.4	9.38	-	0.28	9.1	6.5
	R1-135	-	-	-	33	23	10	<2	<2	-	9.88	6.09	-	0.34	5.7	5.0
	R1	-	-	-	34	25	9	6	4	-	5.34	1.58	-	0.25	4.5	4.0
	R2-50	-	-	-	70	31	39	34	24	-	19.1	14.0	-	0.15	11.5	8.2
	R2-100	-	-	-	43	24	19	10	4	-	15.1	9.94	-	0.22	9.9	7.8
	R2-135	-	-	-	37	27	10	6	4	-	-	5.32	-	0.18	7.7	5.9
	R2	-	-	-	39	27	12	6	<2	-	9.80	3.64	-	0.17	5.4	5.1
	R3	-	-	-	45	25	20	16	4	-	5.57	0.13	-	0.10	4.9	3.6

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)				Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
10-16-79	RS	239	-	-	95	58	37	40	34	-	36.2	26.5	-	0.76	17.7	13.9
	LEFF	39	-	-	51	27	24	44	36	-	7.49	0.13	-	0.04	3.5	2.5
	TSE	7	-	-	40	29	11	20	16	-	4.32	0.32	-	0.05	4.0	3.1
	LPRO	-	-	-	40	28	12	38	34	-	5.43	0.43	-	0.13	2.9	2.1
	R1-50	-	-	-	55	23	32	18	18	-	29.2	26.4	-	0.46	12.5	10.1
	R1-100	-	-	-	28	25	3	8	8	-	11.4	8.87	-	0.56	8.4	7.2
	R1-135	-	-	-	29	24	5	8	8	-	7.93	7.93	-	0.66	7.6	6.3
	R1	-	-	-	30	24	6	4	2	-	5.49	2.36	-	0.41	5.6	5.2
	R2-50	-	-	-	41	27	14	8	8	-	17.3	15.6	-	0.33	11.4	15.0
	R2-100	-	-	-	28	34	?	4	4	-	12.1	9.96	-	0.49	9.2	7.4
	R2-135	-	-	-	30	25	5	2	2	-	15.6	11.8	-	0.48	10.3	-
	R2	-	-	-	30	37	?	4	4	-	5.99	4.08	-	0.57	5.9	5.5
	R3	-	-	-	28	26	2	4	4	-	-	-	-	-	5.6	5.3
	RST	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
10-18-79	RS	-	-	-	63	32	31	42	32	18.8	15.6	12.6	0.87	2.31	6.1	3.9
	R2-25	-	-	-	55	31	24	22	12	28.0	26.5	23.1	1.19	0.34	13.5	8.7
	R2-50	-	-	-	53	31	22	30	20	25.3	23.8	17.9	1.20	0.25	14.2	9.8
	R2-75	-	-	-	44	31	13	24	14	29.7	28.3	22.3	1.18	0.18	10.9	8.7
	R2-100	-	-	-	37	30	7	14	12	22.7	20.8	19.1	1.61	0.28	11.3	8.5
	R2-135	-	-	-	32	27	5	8	6	15.0	13.2	12.4	1.61	0.18	8.9	6.5
	R2	-	-	-	36	30	6	4	4	11.0	7.93	7.33	2.80	0.25	5.7	5.8
10-22-79	RS	-	-	-	133	58	75	70	58	-	19.8	13.7	-	0.62	17.1	11.7
	R2-25	-	-	-	136	65	71	82	64	25.2	23.2	21.0	0.90	1.12	21.2	15.5
	R2-50	-	-	-	72	38	34	48	40	26.5	24.7	14.8	1.09	0.70	13.0	10.7
	R2-75	-	-	-	53	36	17	64	38	35.4	33.9	19.6	1.19	0.34	19.2	14.7
	R2-100	-	-	-	51	35	16	48	36	21.1	20.0	17.7	0.84	0.28	13.1	10.7
	R2-135	-	-	-	43	35	8	32	24	19.4	18.4	14.2	0.67	0.32	12.8	9.9
	R2	-	-	-	39	32	7	38	20	13.1	12.1	8.94	0.67	0.29	8.0	7.6

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)			Nitrogen(mg-N/l)				Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	ISS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
02-21-80	RS	-	-	-	126	34	92	153	100	-	-	-	-	-	-	-
	LEFF	-	-	-	61	27	34	88	80	-	-	-	-	-	-	-
	TSE	-	-	-	39	24	15	37	16	-	-	-	-	-	-	-
02-28-80	RS	-	-	-	130	91	39	93	80	-	-	-	-	0.43	-	4.8
	LEFF	-	-	-	59	33	26	82	65	-	-	-	-	0.25	-	2.2
	TSE	-	-	-	57	36	21	67	44	-	-	-	0.36	0.22	-	2.9
	RI	-	-	-	45	38	7	36	21	-	-	-	0.75	0.24	-	-
	R2-25	-	-	-	160	67	93	52	42	-	-	-	1.34	1.31	-	6.3
	R2-50	-	-	-	104	54	50	80	57	-	-	-	2.71	0.47	-	5.6
	R2-75	-	-	-	121	54	67	73	55	-	-	-	3.38	0.38	-	7.0
	R2-100	-	-	-	73	47	26	72	47	-	-	-	1.67	0.32	-	6.0
	R2-135	-	-	-	86	51	35	121	76	-	-	-	0.88	0.25	-	5.3
	R2	-	-	-	44	36	8	39	30	-	-	-	0.65	0.22	-	4.5

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
03-13-80	RS	108	40	68	78	30	48	103	100	-	-	15.0	-	0.21	3.2	-
	LEFF	17	8	9	57	32	25	55	52	-	-	1.00	-	0.43	3.4	-
	TSE	9	4	5	32	25	7	31	30	-	-	0.77	1.5	<0.14	2.0	-
	R1	26	10	16	28	21	7	19	17	-	-	2.48	1.6	1.81	-	-
	R2-25	58	25	33	62	30	32	55	57	-	-	18.0	2.2	1.33	4.1	-
	R2-50	59	20	39	54	28	26	50	41	-	-	11.0	2.1	0.44	4.0	-
	R2-75	51	17	34	51	26	25	44	36	-	-	10.3	2.7	0.43	4.4	-
	R2-100	37	15	22	33	20	13	47	33	-	-	10.9	1.8	0.43	3.6	-
	R2-135	40	9	31	32	18	14	34	25	-	-	8.40	2.2	0.43	3.3	-
	R2	20	7	13	25	18	7	35	36	-	-	2.47	1.4	1.80	2.7	-
	R3	15	6	9	20	14	6	73	42	-	-	0.82	1.1	1.39	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
03-27-80	RS	62	40	22	89	31	58	119	92	118.1	117.0	45.5	0.65	0.45	-	-
	TSE	5	3	2	35	27	8	30	19	27.5	26.5	<0.14	0.88	<0.14	-	-
	R1	19	6	13	34	24	10	36	28	43.7	42.7	4.85	0.81	<0.14	-	-
	R2-25	96	38	58	139	38	101	532	389	188.1	187.0	66.0	0.75	0.31	-	-
	R2-50	84	33	51	83	34	49	171	76	121.0	120.0	58.0	0.86	0.17	-	-
	R2-75	74	23	51	71	25	46	223	91	105.1	104.0	50.0	0.90	0.16	-	-
	R2-100	37	13	24	36	19	17	134	51	52.5	51.6	12.5	0.77	<0.14	-	-
	R2-135	31	7	24	39	24	15	114	53	44.2	43.2	9.30	0.85	<0.14	-	-
	R2	19	6	13	37	28	9	33	27	28.5	27.8	<0.14	0.52	<0.14	-	-
	R3	16	6	10	30	34	?	37	27	27.1	26.5	<0.14	0.44	<0.14	-	-
04-10-80	RS	153	37	116	91	40	51	110	90	-	-	136.0	0.14	0.66	4.4	2.6
	TSE	6	4	2	35	27	8	27	17	42.3	42.0	0.52	<0.14	0.20	2.9	1.9
	R1	24	9	15	47	30	17	34	25	41.5	41.0	3.40	0.18	0.29	-	-
	R2-25	-	45	-	113	33	80	275	176	68.4	68.0	119.0	<0.14	0.26	6.7	5.7
	R2-50	130	31	99	90	33	57	670	239	21.8	21.5	92.0	<0.14	<0.14	8.6	7.3
	R2-75	69	21	48	58	32	26	99	56	9.28	9.00	58.0	<0.14	<0.14	6.7	6.2
	R2-100	59	14	45	47	28	19	98	85	15.3	15.0	32.5	<0.14	<0.14	7.4	5.2
	R2-135	27	9	18	37	25	12	49	21	34.4	34.0	0.31	0.21	0.14	3.8	2.8
	R2	22	8	14	47	39	8	24	17	2.83	2.55	2.71	<0.14	<0.14	4.7	3.1

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
04-24-80	RS	128	54	74	107	40	67	134	123	-	22.1	14.0	-	0.21	-	-
	LEFF	27	5	22	53	32	21	77	56	8.18	6.30	1.68	1.74	<0.14	-	-
	TSE	11	5	6	43	35	8	26	17	4.80	3.70	<0.14	0.96	<0.14	-	-
	R1	-	8	-	46	37	9	26	18	9.35	7.20	<0.14	2.01	<0.14	-	-
	R2	-	8	-	46	36	10	21	15	4.57	3.30	0.42	1.13	<0.14	-	-
	L1	13	3	10	41	29	12	29	22	4.06	3.10	<0.14	0.56	0.40	-	-
	L2	12	4	9	42	29	13	27	21	4.37	3.50	<0.14	0.56	0.31	-	-
	L3	11	3	8	41	30	11	32	24	3.33	2.90	<0.14	0.29	<0.14	-	-
	L4	-	3	-	41	31	10	32	25	4.21	3.60	<0.14	0.47	<0.14	-	-
05-22-80	RS	177	59	118	73	35	38	154	136	22.9	22.1	15.8	0.63	0.18	-	-
	LEFF	27	11	16	37	18	19	57	47	3.73	3.45	3.05	<0.14	<0.14	-	-
	TSE	8	4	4	33	35	?	26	20	3.46	2.70	2.20	0.62	<0.14	-	-
	R1	16	8	8	32	30	2	24	25	9.28	7.90	-	1.14	0.24	-	-
	R3	16	10	6	32	29	3	23	22	-	-	6.40	1.02	0.23	-	-
	L1	10	4	6	22	30	?	22	19	1.33	1.05	<0.14	<0.14	<0.14	-	-
	L2	13	4	9	23	24	?	27	17	1.63	1.35	<0.14	<0.14	<0.14	-	-
	L3	12	4	8	21	31	?	25	19	1.63	1.35	<0.14	<0.14	<0.14	-	-
	L4	10	3	7	20	19	1	25	22	1.78	1.50	<0.14	<0.14	<0.14	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
05-29-80	RS	117	39	78	67	31	36	111	105	-	-	-	-	-	-	-
	LEFF	41	9	32	46	27	19	90	66	-	-	-	-	-	-	-
	TSE	17	6	11	39	34	5	30	31	-	-	-	-	-	-	-
	R1	17	5	12	39	34	5	15	19	-	-	-	-	-	-	-
	R2-25	91	49	42	70	44	26	96	81	-	-	-	-	-	-	-
	R2-50	67	24	43	59	39	20	75	66	-	-	-	-	-	-	-
	R2-75	57	20	37	61	36	25	56	50	-	-	-	-	-	-	-
	R2-100	37	13	24	40	33	7	39	25	-	-	-	-	-	-	-
	R2-135	26	12	14	41	36	5	41	22	-	-	-	-	-	-	-
	R2	15	6	9	47	41	6	14	9	-	-	-	-	-	-	-
	L1	21	6	15	42	34	8	35	29	-	-	-	-	-	-	-
	L2-25	49	13	36	60	34	26	114	86	-	-	-	-	-	-	-
	L2-50	-	9	-	56	35	21	95	72	-	-	-	-	-	-	-
	L2-75	33	6	27	46	37	9	65	49	-	-	-	-	-	-	-
	L2-100	26	5	21	42	29	13	57	39	-	-	-	-	-	-	-
	L2-125	-	5	-	39	29	10	57	31	-	-	-	-	-	-	-
	L2	20	4	16	37	29	8	37	23	-	-	-	-	-	-	-
	L3	24	4	20	38	30	8	38	27	-	-	-	-	-	-	-
	L4	24	5	19	39	34	5	39	30	-	-	-	-	-	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
06-25-80	RS	124	43	81	77	34	43	160	148	22.9	22.1	12.6	0.6	0.20	2.9	2.3
	LEFF	37	2	35	57	20	37	108	103	9.46	8.20	0.33	1.12	<0.14	3.7	2.2
	TSE	18	1	17	37	25	12	47	43	7.07	5.75	2.50	1.18	<0.14	6.1	2.2
	R1	5	3	2	36	35	1	-	-	2.66	1.20	<0.14	1.32	<0.14	-	-
	R2-25	24	22	2	50	25	25	42	36	13.2	12.1	10.0	0.96	0.18	3.5	2.9
	R2-50	21	9	12	43	21	22	45	39	11.6	10.8	10.1	0.69	0.15	4.7	3.2
	R2-75	21	12	9	40	17	23	42	39	10.2	9.60	9.75	0.44	0.15	3.7	3.4
	R2-100	12	10	2	30	20	10	44	36	10.5	9.60	9.70	0.72	<0.14	3.8	3.4
	R2-135	9	6	3	27	19	8	22	17	8.54	7.65	8.30	0.75	<0.14	3.9	3.8
	R2	6	4	2	26	20	6	17	14	-	-	6.70	0.41	0.14	<0.1	<0.1
	L1	13	2	11	44	27	17	73	68	6.25	4.80	<0.14	1.31	<0.14	-	-
	L2	15	2	13	43	25	18	68	61	5.43	4.80	<0.14	0.49	<0.14	-	-
	L3	17	2	15	46	23	23	82	72	5.13	4.35	<0.14	0.64	<0.14	-	-
	L4	18	2	16	46	37	9	82	75	5.60	4.85	<0.14	0.61	<0.14	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
07-03-80	RS	139	46	93	90	41	49	253	216	33.3	32.5	19.5	0.74	0.06	12.1	9.1
	LEFF	65	8	57	66	35	31	132	124	13.7	13.0	1.52	0.68	0.02	4.9	3.0
	TSE	11	5	6	46	36	10	34	29	9.36	4.70	1.86	4.60	0.06	4.4	3.0
	R2-25	71	43	28	76	40	36	70	61	22.9	21.8	16.2	1.06	0.03	7.5	6.0
	R2-50	52	19	33	60	35	25	56	51	17.7	17.0	14.6	0.70	0.03	6.4	5.7
	R2-75	41	13	28	56	30	26	52	45	11.5	10.8	9.80	0.65	0.04	6.0	5.6
	R2-100	29	10	19	42	31	11	34	31	12.2	10.5	7.90	1.68	0.04	5.4	4.9
	R2-135	24	5	19	38	30	8	42	35	9.55	7.10	2.96	2.40	0.05	5.3	4.6
	R2	21	5	16	44	33	11	28	26	12.7	7.30	1.61	5.30	0.10	4.8	3.4
	L1	13	3	10	36	30	6	52	47	5.03	4.20	<0.14	0.82	0.01	-	-
	L2	9	2	7	40	32	8	42	39	4.19	3.50	<0.14	0.69	0.00	-	-
	L3	8	3	5	41	29	12	48	42	4.06	3.50	<0.14	0.56	0.00	-	-
	L4	9	2	7	41	32	9	48	42	3.45	2.90	<0.14	0.54	0.01	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
07-09-80	RS	187	44	143	107	48	59	234	196	32.0	31.8	19.0	0.22	0.00	8.4	10.4
	LEFF	16	2	14	60	34	26	89	76	9.72	9.20	<0.14	0.49	0.03	3.3	2.5
	TSE	3	2	1	33	29	4	17	11	8.49	7.40	4.60	1.08	0.01	2.6	2.6
	R2-25	88	38	50	77	47	30	71	61	25.6	25.5	17.2	0.11	0.00	6.5	5.2
	R2-50	58	36	22	66	41	25	37	30	23.2	23.0	18.5	0.21	0.01	5.9	4.9
	R2-75	66	21	45	61	40	21	40	31	22.0	21.8	18.0	0.22	0.02	5.5	4.4
	R2-100	36	10	26	41	34	7	39	31	15.6	15.1	11.4	0.41	0.04	5.0	4.0
	R2-135	26	3	23	35	27	8	19	14	19.1	18.7	15.8	0.31	0.07	4.4	3.6
	R2	14	4	10	29	23	6	11	9	11.6	11.0	9.70	0.53	0.09	3.7	3.4
	L1	13	3	10	47	34	13	55	46	4.17	3.80	<0.14	0.36	0.01	-	-
	L2	11	2	9	49	33	16	49	41	4.83	4.45	<0.14	0.37	0.01	1.7	-
	L3	17	3	14	48	34	14	54	41	5.12	4.20	0.49	0.89	0.03	1.5	1.1
	L4	13	1	12	48	33	15	51	37	3.19	2.70	<0.14	0.48	0.01	1.7	1.3

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
07-16-80	RS	-	-	-	148	40	108	376	313	32.6	32.4	19.3	0.20	0.01	5.9	5.3
	LEFF	-	-	-	84	37	47	140	131	17.3	17.1	<0.14	0.15	0.01	3.9	3.5
	TSE	-	-	-	60	44	16	61	54	6.53	6.37	<0.14	0.15	0.01	2.8	2.6
	R2	-	-	-	54	45	9	22	20	11.1	7.00	0.29	4.05	0.04	4.7	4.3
	L2-25	-	-	-	74	40	34	115	108	13.7	13.5	<0.14	0.19	0.01	4.1	3.7
	L2-50	-	-	-	70	37	33	107	99	8.56	8.19	<0.14	0.36	0.01	3.8	3.3
	L2-75	-	-	-	63	35	28	91	80	7.30	7.14	<0.14	0.15	0.01	3.2	3.0
	L2-100	-	-	-	64	35	29	92	74	9.40	9.10	<0.14	0.29	0.01	3.0	2.8
	L2-125	-	-	-	60	36	24	76	74	11.1	10.9	<0.14	0.22	0.01	3.2	2.9
	L2	-	-	-	61	36	25	68	64	10.0	9.70	<0.14	0.29	0.01	3.2	2.7
	L4	-	-	-	61	34	27	74	67	8.53	8.40	<0.14	0.12	0.01	3.0	2.7

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
07-23-80	RS	73	23	50	99	39	60	137	123	28.5	28.5	14.7	0.01	0.01	5.5	5.1
	LEFF	31	1	30	67	34	33	109	100	15.3	14.8	<0.14	0.52	0.02	4.0	4.2
	TSE	15	6	9	56	40	16	48	42	11.4	9.80	<0.14	1.57	0.02	2.9	3.0
	R2-25	45	12	33	77	47	30	53	49	30.5	28.8	15.5	1.36	0.29	7.5	6.2
	R2-50	27	7	20	60	32	28	52	45	25.2	25.1	16.5	0.08	0.03	6.0	5.4
	R2-75	12	4	8	56	33	23	35	30	18.9	18.2	9.09	0.62	0.04	4.9	4.8
	R2-100	7	5	2	44	33	11	71	30	13.1	12.5	6.38	0.53	0.08	4.4	4.2
	R2-135	9	5	4	43	34	9	26	24	9.38	8.44	3.60	0.88	0.06	4.3	4.1
	R2	11	2	9	43	35	8	24	19	8.22	6.90	0.73	1.26	0.06	4.9	3.9
	L1	9	1	8	57	38	19	67	62	11.3	10.9	<0.14	0.36	0.01	-	-
	L2	19	1	18	58	38	20	68	64	11.5	10.7	<0.14	0.82	0.01	2.8	2.9
	L3	7	2	5	54	39	15	70	64	12.5	12.1	<0.14	0.35	0.02	-	-
	L4	10	1	9	61	38	23	68	63	12.2	12.0	<0.14	0.20	0.01	2.7	2.9

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
07-30-80	RS	119	37	82	79	36	43	118	101	36.1	36.0	17.6	0.06	0.01	8.6	7.5
	LEFF	34	4	30	56	32	24	98	89	14.3	14.2	0.26	0.06	0.01	3.7	3.7
	TSE	19	8	11	48	36	12	46	45	8.72	7.84	0.18	0.87	0.01	2.9	3.0
	R2-25	82	24	58	61	34	27	83	74	31.5	31.3	16.8	0.20	0.02	7.6	7.5
	R2-50	60	16	44	45	32	13	68	58	25.4	25.1	12.7	0.28	0.02	6.6	5.4
	R2-75	40	14	26	41	28	13	48	43	21.7	21.4	11.4	0.30	0.02	5.7	5.0
	R2-100	22	9	13	36	28	8	45	31	17.6	16.4	7.28	1.16	0.03	5.1	4.5
	R2-135	21	5	16	33	31	2	36	27	13.9	11.1	2.07	2.78	0.02	4.9	4.4
	R2	13	4	9	34	32	2	17	16	9.91	7.13	1.54	2.76	0.02	3.9	3.9
	L4	13	2	11	54	35	19	79	69	13.5	13.5	0.06	0.02	0.01	2.7	2.6

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
08-21-80	RS	117	41	76	110	37	73	190	166	29.0	29.0	12.9	0.03	0.01	-	-
	LEFF	26	2	24	61	40	21	76	75	16.4	16.2	0.26	0.16	0.02	-	-
	TSE	11	4	7	51	44	7	21	19	10.8	10.6	3.57	0.21	0.01	-	-
	R2-25	67	32	35	76	46	30	-	-	27.1	26.8	15.3	0.25	0.06	-	-
	R2-50	59	19	40	75	43	32	-	-	29.1	27.5	15.8	1.42	0.13	-	-
	R2-75	50	14	36	60	46	14	-	-	28.5	26.2	15.1	2.28	0.06	-	-
	R2-100	41	12	29	56	42	14	-	-	23.4	23.4	13.9	0.00	0.02	-	-
	R2-135	27	6	21	51	43	8	-	-	21.2	21.1	12.0	0.06	0.02	-	-
	R2	26	6	20	53	46	7	25	23	19.5	19.3	11.8	0.16	0.02	-	-
	L2	14	2	12	56	47	9	31	28	8.26	8.20	0.21	0.05	0.01	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
09-17-80	LEFF	-	-	-	76	39	37	143	130	-	-	-	-	-	-	-
	TSE	-	-	-	53	43	10	44	38	-	-	-	-	-	-	-
	L2	-	-	-	-	-	-	74	75	-	-	-	-	-	-	-
12-13-80	LEFF	-	-	-	50	-	-	33	32	-	-	-	-	-	-	-
	TSE	-	-	-	41	-	-	25	20	-	-	-	-	-	-	-
	L2	-	-	-	43	-	-	25	22	-	-	-	-	-	-	-
	L3	-	-	-	43	-	-	-	-	-	-	-	-	-	-	-
	L4	-	-	-	-	-	-	20	19	-	-	-	-	-	-	-
02-03-81	RS	223	-	-	128	-	-	178	-	-	-	-	-	-	9.1	-
	LEFF	16	-	-	61	-	-	63	-	-	-	-	-	-	4.5	-
	TSE	15	-	-	50	-	-	43	-	-	-	-	-	-	4.0	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
03-10-81	LEFF	23	-	-	65	-	-	75	-	-	-	-	-	-	-	-
	TSE	16	-	-	48	-	-	46	-	-	-	-	-	-	-	-
	L2-25	20	-	-	59	-	-	76	-	-	-	-	-	-	-	-
	L2-50	23	-	-	52	-	-	59	-	-	-	-	-	-	-	-
	L2-75	19	-	-	49	-	-	54	-	-	-	-	-	-	-	-
	L2-100	16	-	-	50	-	-	54	-	-	-	-	-	-	-	-
	L2-125	17	-	-	51	-	-	56	-	-	-	-	-	-	-	-
	L2	16	-	-	48	-	-	47	-	-	-	-	-	-	-	-
03-17-81	LEFF	36	-	-	68	-	-	76	-	-	-	-	-	-	-	-
	TSE	13	-	-	44	-	-	30	-	-	-	-	-	-	-	-
	L2-25	30	-	-	59	-	-	68	-	-	-	-	-	-	-	-
	L2-50	27	-	-	60	-	-	56	-	-	-	-	-	-	-	-
	L2-75	21	-	-	50	-	-	50	-	-	-	-	-	-	-	-
	L2-100	20	-	-	52	-	-	58	-	-	-	-	-	-	-	-
	L2-125	19	-	-	50	-	-	48	-	-	-	-	-	-	-	-
	L2	14	-	-	49	-	-	43	-	-	-	-	-	-	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
05-15-81	RS	166	-	-	71	-	-	133	-	-	-	-	-	-	-	-
	LEFF	40	-	-	59	-	-	113	-	-	-	-	-	-	-	-
	TSE	9	-	-	44	-	-	18	-	-	-	-	-	-	-	-
	L2	13	-	-	43	-	-	21	-	-	-	-	-	-	-	-
	L4	15	-	-	42	-	-	22	-	-	-	-	-	-	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
05-28-81	RS	164	-	-	91	-	-	136	-	-	-	-	-	-	4.3	-
	LEFF	-	-	-	70	-	-	105	-	-	-	-	-	-	5.2	-
	TSE	25	-	-	57	-	-	53	-	-	-	-	-	-	4.8	-
	TSE-CL	-	-	-	59	-	-	59	-	-	-	-	-	-	4.2	-
	L3	24	-	-	56	-	-	43	-	-	-	-	-	-	3.8	-
	L4-25	49	-	-	65	-	-	80	-	-	-	-	-	-	4.1	-
	L4-50	35	-	-	60	-	-	70	-	-	-	-	-	-	4.2	-
	L4-75	-	-	-	59	-	-	57	-	-	-	-	-	-	4.3	-
	L4-100	23	-	-	56	-	-	41	-	-	-	-	-	-	5.5	-
	L4-125	18	-	-	54	-	-	33	-	-	-	-	-	-	4.8	-
	L4	22	-	-	53	-	-	35	-	-	-	-	-	-	4.2	-
06-04-81	RS	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	-
	LEFF	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	-
	TSE	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
06-11-81	RS	136	-	-	92	-	-	79	-	-	-	-	-	-	2.2	-
	LEFF	22	-	-	56	-	-	32	-	-	-	-	-	-	2.5	-
	TSE	5	-	-	53	-	-	7	-	-	-	-	0.03	-	2.5	-
	TSE-Cl	11	-	-	53	-	-	6	-	-	-	-	-	-	2.5	-
	L3	7	-	-	51	-	-	5	-	-	-	-	-	-	2.7	-
	L4-25	15	-	-	55	-	-	22	-	-	-	-	-	-	-	-
	L4-50	13	-	-	53	-	-	12	-	-	-	-	-	-	-	-
	L4-75	14	-	-	60	-	-	15	-	-	-	-	-	-	-	-
	L4-100	12	-	-	57	-	-	10	-	-	-	-	-	-	-	-
	L4-125	9	-	-	52	-	-	10	-	-	-	-	-	-	-	-
	L4	12	-	-	53	-	-	7	-	-	-	-	-	-	3.0	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)			Nitrogen(mg-N/l)				Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
06-25-81	RS	396	-	-	>160	-	-	-	-	-	-	-	-	-	10.8	-
	LEFF	52	-	-	68	-	-	114	-	-	-	-	-	-	4.4	-
	TSE	12	-	-	52	-	-	31	-	-	-	-	0.41	-	3.8	-
	L3	4	-	-	46	-	-	11	-	-	-	-	-	-	2.8	-
	L4-25	52	-	-	77	-	-	122	-	-	-	-	-	-	-	-
	L4-50	22	-	-	57	-	-	59	-	-	-	-	-	-	-	-
	L4-75	14	-	-	53	-	-	35	-	-	-	-	-	-	-	-
	L4-100	15	-	-	53	-	-	33	-	-	-	-	-	-	-	-
	L4-125	-	-	-	51	-	-	9	-	-	-	-	-	-	-	-
	L4	4	-	-	49	-	-	12	-	-	-	-	-	-	3.5	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)				Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
07-20-81	RS	119	-	-	72	-	-	130	-	-	-	8.20	-	-	3.1	-
	LEFF	40	-	-	72	-	-	143	-	-	-	0.04	-	-	5.4	-
	TSE	4	-	-	42	-	-	-	-	-	-	0.09	-	-	3.4	-
	TSE-Cl	-	-	-	-	-	-	12	-	-	-	0.05	-	-	3.4	-
	L3	2	-	-	49	-	-	11	-	-	-	0.07	-	-	2.9	-
	L4-25	32	-	-	58	-	-	63	-	-	-	0.18	-	-	-	-
	L4-50	14	-	-	53	-	-	26	-	-	-	0.04	-	-	-	-
	L4-75	8	-	-	43	-	-	19	-	-	-	0.05	-	-	-	-
	L4-100	8	-	-	45	-	-	20	-	-	-	0.07	-	-	-	-
	L4-125	8	-	-	46	-	-	22	-	-	-	0.10	-	-	-	-
	L4	4	-	-	48	-	-	9	-	-	-	0.10	-	-	3.8	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
08-05-81	RS	>900	-	-	>160	-	-	800	-	-	-	-	-	-	-	-
	LEFF	37	-	-	69	-	-	93	-	-	-	-	-	-	-	-
	TSE	13	-	-	54	-	-	18	-	-	-	-	-	-	-	-
	TSE-Cl	15	-	-	54	-	-	20	-	-	-	-	-	-	-	-
	L3	11	-	-	54	-	-	10	-	-	-	-	-	-	-	-
	L4-25	58	-	-	79	-	-	152	-	-	-	-	-	-	-	-
	L4-50	26	-	-	56	-	-	56	-	-	-	-	-	-	-	-
	L4-75	27	-	-	60	-	-	57	-	-	-	-	-	-	-	-
	L4-100	27	-	-	57	-	-	51	-	-	-	-	-	-	-	-
	L4-125	22	-	-	58	-	-	44	-	-	-	-	-	-	-	-
	L4	11	-	-	61	-	-	-	-	-	-	-	-	-	-	-

TABLE A-1, cont.

Date	Sample Location	BOD(mg/l)			TOC(mg/l)			Solids(mg/l)		Nitrogen(mg-N/l)					Phos.(mg-P/l)	
		Tot.	Sol.	Part.	Tot.	Sol.	Part.	TSS	VSS	Tot.	TKN	NH	NO	NO	Tot.	Ortho
08-13-81	RS	>365	-	-	244	56	188	720	633	-	-	14.1	-	-	10.2	-
	LEFF	43	5	38	80	45	35	126	109	-	-	1.65	-	-	5.5	-
	TSE	4	2	2	40	37	3	16	14	-	-	0.07	-	-	3.3	-
	L3	3	2	1	38	33	5	8	8	-	-	0.04	-	-	2.6	-
	L4-25	29	5	24	62	42	20	56	52	-	-	0.50	-	-	-	-
	L4-50	17	4	13	52	42	10	44	40	-	-	0.13	-	-	-	-
	L4-75	15	3	12	46	40	6	36	32	-	-	0.04	-	-	-	-
	L4-100	13	3	10	45	37	8	28	24	-	-	0.02	-	-	-	-
	L4-125	8	2	6	40	35	5	19	18	-	-	0.02	-	-	-	-
	L4	7	2	5	39	35	4	19	17	-	-	0.05	-	-	3.2	-
09-18-81	RS	>600	-	-	>160	-	-	1235	-	-	-	-	-	-	-	-
	LEFF	57	-	-	67	-	-	134	-	-	-	-	-	-	-	-
	TSE	5	-	-	50	-	-	20	-	-	-	-	-	-	-	-
	L2	16	-	-	51	-	-	29	-	-	-	-	-	-	-	-
	L3	11	-	-	47	-	-	19	-	-	-	-	-	-	-	-
	L4	6	-	-	44	-	-	16	-	-	-	-	-	-	-	-